IASPEI

The International Association of Seismology and Physics of the Earth's Interior

International Association of Seismology and Physics of the Earth's Interior

Committee on Education
Report No. 2

Current Status of the "International Handbook of Earthquake and Engineering Seismology"

Draft for Web: June 15, 1998

Introduction

Modern scientific investigations of earthquakes began in the 1880's, and the International Association of Seismology was organized in 1901 to promote collaboration of scientists and engineers in studying earthquakes. With rapid advances in the 20th century, many branches of seismology developed and there is not an authoritative reference that summarizes our present knowledge about earthquake and engineering seismology. We think it is appropriate that an international handbook be published on the occasion of the Association's centennial in 2001. It is our hope that this Handbook will help to bridge the gap between seismologists and earthquake engineers and will be truly international in scope. Our aims for the Handbook are:

- to summarize the well established facts,
- to review relevant theories,
- to survey useful methods and techniques, and
- to document and archive basic seismic data.

It will consist of about 84 chapters grouped into 10 parts, with 3 CD-ROMs containing materials to augment the printed chapters, and including a compilation of seismic data from around the world and a global earthquake database with software for displaying seismicity maps. We plan to have the manuscripts ready by the summer of 1999, reviewed and revised by the summer of 2000, and published in the year 2001. For more details, please visit our Web site: **http://caldera.wr.usgs.gov**

It is also our desire to prepare an affordable publication. Academic Press will publish the Handbook as a 1,200 page, 8 1/2 by 11-inch casebound volume with 3 CD-ROMs, for a price of about $150.

The publication of this Handbook is under the auspices of the Committee on Education of the International Association of Seismology and Physics of the Earth's Interior (IASPEI). The Handbook will be edited by Willie Lee, Hiroo Kanamori, and Paul C. Jennings. To help us in organizing the contents of the Handbook and in reviewing manuscripts, we have organized an editorial advisory board with the following members:

- **Honorary Chairmen**: George Housner and Frank Press
- **Members:** Robin Adams, Kei Aki, Nick N. Ambraseys, Bruce Bolt, Enzo Boschi, Juan S. Carmona, Yun-tai Chen, V. (Slava) Cerveny, Shel Cherry, C. B. Crouse, Bob Engdahl, Luis Esteva, Claude Froidevaux, Yoshio Fukao, Karl Fuchs, Slawomir Gibowicz, Domenico Giardini, Harsh Gupta, Eystein Husebye, Dave Jackson, Sudhir K. Jain, Raymond Jeanloz, Edgar Kausel, Brian Kennett, Andrzej Kijko, Ota Kulhanek, Graeme McVerry, Saburoh Midorikawa, Tadeo Minami, Alexei Nikolaev, Basil Papazachos, Barbara Romanowicz, Paul Silver, Shri K. Singh, Paul Spudich, Carl Stepp, Yi-Ben Tsai, Seiya Uyeda, Hiroshi Wakita, John Wolf, Ray Willemann, Li-Li Xie, and Mary Lou Zoback.

We welcome comments and suggestions. Please send them by email to Willie Lee at: whklee@ix.netcom.com or lee@usgs.gov

The contents of the Handbook at present are shown below. All listed authors have agreed to contribute their articles with the titles shown here. A "*" indicates that the article is tentative. The grouping of chapters into parts is tentative and we expect some changes in the final publication.

Handbook Contents

These CD-ROMs contain the following materials:

* Additional materials from the printed chapters (especially Parts V & X)
* A compilation of earthquake catalogs around the world.
* A global earthquake database with search and display software.
* Selected public software for earthquake and engineering seismology (chapter authors).
* Digital imagery of faults, earthquakes, volcanoes and their effects.

Chapter Outlines of

"International Handbook of Earthquake and Engineering Seismology"

Edited by

William H. K. Lee, Hiroo Kanamori, and Paul C. Jennings

Draft for the Web: June 15, 1998

Chapter 1. History of Seismology

Duncan Agnew
IGPP, University of California, La Jolla, CA , USA

The aim of an article on the history of seismology should be to cover the development of methods and ideas, especially for periods prior to what is "current". Such an article eliminates the need for historical introductions in the individual articles. It also provides a location for an overview, relating developments in seismology to changes in other sciences, technological changes, and changes in society (notably in what kinds of research were funded). The temporal coverage would be from the time at which earthquakes were first treated as natural phenomena, up to the time at which a current review would reasonably begin (probably around 1980).

While some attention to "firsts" is unavoidable, I will try to pay more attention to the times at which different developments became common in the general seismological community, and to lineages of ideas.

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IV. Newer Developments (Starting in the 1950's and 1960's)

1. Detecting nuclear testing: a new motivation
2. Expanding the instrumental envelope: Press, Ewing, the WWSSN, seismic arrays and networks, and
   $ the beginnings of digital recording
3. Beyond first arrivals (I): surface waves
4. Beyond first arrivals (II): free oscillations
5. Beyond first arrivals (III): body-wave modeling
6. Studies of the crust: Tuve, Early Rise and Deep Seismic Sounding
7. Earthquake prediction programs: another new motivation
8. Understanding earthquakes (I): focal mechanisms, seismotectonics, and plate tectonics
9. Understanding earthquakes (II): improving theories (rock mechanics and dislocation theory)

** Manuscript submission date: 31 August 1998

(3/9/98)

Chapter 2. History of Earthquake Engineering*

*** This Chapter is being organized now. ***

Chapter 3. International Seismology

R. D. Adams
International Seismological Centre, Thatcham, UK

This chapter will cover the development of international seismology particularly from the beginning of the instrumental era at the end of last century. It will discuss developments in the international exchange of earthquake readings, leading to global earthquake location, and the parallel development of international bodies for the discussion and planning of joint earthquake activities and research on a global scale.

It will concentrate more on the early historical aspects, particularly of the international associations, and will attempt to bring out the dedication of the early pioneers and the administrative and logistic difficulties they faced and overcame.

Table of Contents (tentative)

** Manuscript submission date: end of 1998.

(7/24/97)

Chapter 4.

Continental Drift, Sea-floor Spreading, and Plate/Plume Tectonics

Seiya Uyeda, Tokai University, Shimizu, Japan
and
Sigenori Maruyama, Tokyo Institute of Technology, Tokyo, Japan

We will try to outline the conceptual development from fixist view to mobilist view in historical perspective. Presentation of continental drift theory (Wegener), its death and revival by paleomagnetism (Runcorn, Blackett), sea-floor spreading hypothesis (Hess, Dietz) and its verification by marine magnetic information combined with geomagnetic reversal discoveries (Cox, Doell, Vine-Matthews), introduction of plate tectonics and related concepts, such as transform faults and hot spots (Wilson, McKenzie-Parker, Morgan, LePichon), application of plate tectonics to orogeny (Dewey-Bird), importance of subduction in driving mechanism and continent formation (Forsyth-Uyeda, Maruyama and many others), Plume tectonics and general history of earth (Maruyama).

Table of Contents (tentative)

** Manuscript submission date: August, 1999.

(4/24/98)

Chapter 5. Earthquakes and Plate Tectonics

Seth Stein
Northwestern University, Evanston, Illinois, USA

Earthquake seismology has played a major role in the development of our current understanding of global plate tectonics. As earthquakes occur primarily at the boundaries between lithospheric plates, the distribution of earthquakes is used to map plate boundaries and the focal mechanisms of earthquakes are used to determine the motion occurring at each boundary. In this chapter we sketch a few of the basic results.

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** Manuscript submission date: February, 1999.

(5/7/98)

Chapter 6. Foundations of Theoretical Seismology

Agustin Udias
Universita Complutense de Madrid, Madrid, Spain

This chapter will treat on the fundamentals of theoretical seismology. Starting from the fundamental equations of elastodynamics will deal with their application to seismic wave generation and propagation. The Earth is considered as an imperfectly isotropic elastic material with plane or spherical geometry. Elastic response of the Earth to earthquakes can be treated as propagating waves or normal mode free vibrations. Energy propagation leads to the phenomenon of dispersion. For high frequencies the ray theory approximation is useful. Source theory is treated from kinematic and dynamic approaches. The moment tensor point source approximation is a useful tool. Realistic dynamic fracture models imply complex finite sources with variable friction and stress distribution on the fault plane.

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** Manuscript to be submitted: February 28, 1999.

(Revised 2/1/98)

Chapter 7. Earthquake Dynamics

Raul I. Madariaga, Ecole Normale Superieure, Paris, France
and
Kim B. Olsen, University of California, Santa Barbara, USA

We study the propagation of seismic ruptures along a fault surface, subject to a heterogeneous stress distribution and inhomogeneous frictional parameters. When prestress is uniform, rupture propagation is simple and is very well modeled by the circular shear crack models of Kostrov and others. In this simple model, all the relevant parameters scale with the fault length. When stress is heterogeneous, rupture propagation changes completely and is controlled by local length scales determined by the initial stress distribution as well as by the distribution of rupture resistance. Thus short rise times (Heaton pulses), rupture arrest, stopping phases, etc are closely controlled by the stress field around the fault. We are only starting to explore the physics of rupture in a heterogeneous stress environment; we expect this to be an important subject of future research. As important as stress heterogeneity (transient heterogeneity) is probably the small scale geometry of faulting. Its integration in fault models is difficult because most of the observations of fault rupture are still limited to the range of frequencies of less than 1 Hz or about 3 km wavelength. This is too coarse a resolution to observe effects of complex geometry other than major fault segmentation as in Landers or Kobe. High frequency seismic radiation is probably the only source of information about small-scale geometry.

Table of Contents (tentative)

** Manuscript submission date: August 31, 1998.

(11/25/97)

Chapter 8. Seismic Ray Theory

Chris Chapman
Schlumberger Cambridge Research, Cambridge, UK

This chapter will review computing ray theory Green's functions in the Earth. As the theory is most straightforward for an anisotropic media with 3 non-degenerate wave types, this is taken as the starting point. The kinematic and dynamic ray equations, including the reflection/transmission coefficients and KMAH index will be discussed for a 3D heterogeneous, anisotropic Earth. These results can then be specialized to simpler Earth models. Isotropy apparently simplifies the equations but makes the shear wave polarization more complicated to compute. The equations can also be simplified for 2D or 1D Earth models. For 1D, isotropic Earth models, we obtain the standard (Bullen) ray equations. The theory can also be generalized to cover situations in which ray theory breaks down. Maslov asymptotic ray theory allows Green's functions to be computed at ray singularities (caustics, critical points, etc.). The Kirchhoff surface integral method models diffracted signals for reflections from non-planar surfaces. Finally, the degeneracy when the 2 shear wave velocities become equal can be handled with quasi-isotropic ray theory.

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**Manuscript submission date: February 28, 1999.

(1/21/98)

Chapter 9. Synthetic Seismograms

Robert B. Herrmann
Saint Louis University, St. Louis, MO, USA

Generating synthetic seismograms for source and structure studies is painful because of incompatible input and output formats of most programs.

A new approach is taken by defining a uniform earth model format and time series format that are compatible with all techniques: modal summation, wavenumber integration, Cagniard-de Hoop generalized ray, and asymptotic ray theory. Output time series are readily converted to SAC or other formats.

A package for computing synthetic seismograms in 1-D media will be provided on CDROM. Executables for MS-DOS, and source code with makefiles for Solaris, OSF-1, LINUX and MS-DOS, manual pages and tutorial in PostScript will be provided. The package uses its own graphics library which is provided to support MS-DOS graphics as well as X11 interactive graphics and PostScript.

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** Manuscript submission date: August, 1998.

(8/14/97)

Chapter 10. Direct Solution Methods in Seismology

Robert J. Geller
The University of Tokyo, Tokyo, Japan

Accurate and efficient computation of synthetic seismograms is important for a wide variety of research in global seismology. Modal superposition is an effective approach for computation of surface wave synthetics (where only the fundamental and first several overtone branches need be summed in most cases), but is not well suited to computation of body wave synthetics, or to 3-D (laterally and vertically) heterogeneous Earth models, as a large number of modes must be computed and summed.

Direct solution methods are in many cases preferable to modal superposition as a method for computing synthetics. This chapter will explain what direct solution methods are, summarize the underlying mathematical theory, discuss computational algorithms, and give computational and numerical examples. It is possible that software will also be included on the CD version, but this is subject to further discussion with the editors. Emphasis will be placed on DSM applications to global-scale problems in spherical coordinates, but DSM approaches in Cartesian or cylindrical coordinates will also be discussed.

Table of Contents (tentative)

** Manuscript submission date: August 31, 1998.

(1/23/98)

Chapter 11. Scattering and Attenuation of Seismic Waves in the Lithosphere

Haruo Sato, Tohoku University, Sendai, Japan,
Mike Fehler, Los Alamos National Laboratory, Los Alamos, NM, USA,
and
Ru-Shan Wu, University of California, Santa Cruz, CA, USA

This chapter covers recent developments in observational and theoretical studies on scattering and attenuation of high-frequency seismic waves in the earth's lithosphere. We focus on the stochastic treatment of the scattering phenomena of seismic waves and the random inhomogeneities of the earth medium.

The excitation of coda waves and their smooth decay are the most prominent phenomena characterized by the existence of random heterogeneities distributed in the earth medium. On the basis of the energy conservation, the excitation of coda waves means the scattering attenuation of direct-wave amplitude with travel distance. We compile recent measurements of Qs and Qp in the lithosphere, and show a possible explanation by scattering lossin random media.

We introduce the radiative transfer theory for explaining the characteristics of seismogram envelopes of local earthquakes, such as spatially uniform distribution of coda energy at a long lapse-time. We also show the seismic albedo analysis and the inversion for the source-energy radiation as applications.

Amplitude and phase of seismic waves are distorted after traveling through the randomly inhomongeneous earth medium as measured by seismic arrays. We show the parabolic approximation for the wave equation in order to explain these measurements in relation with the spectral structure of the random inhomogeneities. Taking stochastic average, we can derive the broadening of seismogram envelopes with increasing travel distance as observed. We also introduce the complex-phase screen method for synthesizing full-elastic wave propagation through random media as a fast code.

Table of Contents (tentative)

** Manuscript submission date: February 28, 1999.

(12/5/97)

Chapter 12. Earthquakes as a Complex System

Donald L. Turcotte and Bruce D. Malamud
Cornell University, Ithaca, NY, USA

The contents will focus on the distribution of earthquakes in magnitude, space and time. The validity of fractal distributions will be discussed as well as their applicability to earthquake hazard assessments. Slider-block models will be introduced and their relevance to chaos and self-organized criticality will be considered. Applications of these concepts to earthquake prediction will be discussed. An example is log-periodic behavior.

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** Manuscript submission date: August 31, l998.

(1/27/98)

Chapter 13. Physics of Earthquakes

Roman Teisseyre and Eugeniusz Majewski
Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland

1) Defects and Internal Stressses

The influence of defect content on the bulk material parameters is explained; the impurities, vacancies and dislocations are present even in the most pure crystals. Materials, like rocks contain also microcracks; in microcracks material continuity is broken. Microcracks can drastically influence the effective bulk parameters, especially, the material strength characteristics.

A defects role as the sources of internal stresses is examined; thermal and dislocation nuclei can effectively help in processes of stress build up; an internal stress concentration may exceed the external stress load by orders of value.

2) Microscopic Approach to Fracturing

Depending on the stress level and material properties, we have to consider the different modes to accommodate deformations: elastic distortion, plastic flow, phase changes, nucleation and growth of ductile microvoids, nucleation and growth of brittle microcracks, nucleation and growth of shear instabilities.

The nucleation of microcracks causes growth of internal stresses, while the formation of instabilities, microcrack coalescences and fragmentation processes lead to fracturing. Fractal theory is briefly discussed to explain the size distribution of fragments and shear bands. Depending on conditions also the creep processes may lead to fracturing.

3) Crack Propagation, Instabilities and Fracturing

The formation of plastic zones at the tip of crack are explained by the activation and interactions of small microcracks, while the crack motion is related to their growth and coalescences. Fracture instabilities depend mainly on the frictional properties of material; here, a special attention is paid to slip weakening and to preexisting tectonic faults. Healing processes on the faults are also included.

4) Pore Water, Phase Transformations and Stress Corrosion

A role of water in pores is examined from the point of view of fracturing processes. The rapid phase transformation as a model of deep earthquakes is shortly presented. Finally, we discuss a problem of stress corrosion; action of some chemical agents and their migration at the crack tip may accelerate the crack fracturing processes. The empirical data related to the stress intensity and the crack velocity, are discussed.

5) Earthquake Thermodynamics

Thermodynamics of irreversible processes is outlined and problems of earthquake thermodynamics -- including the energy release, seismic efficiency and entropy production -- are discussed and summarized. Also a relation between the phenomenological and the microscopic approaches is explained.

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** Manuscript submission date: February 28, 1999.

(3/27/98)

Chapter 14. Inverse Problems

Albert Tarantola and Christophe Barnes
Institut de Physique du Globe de Paris, Paris, France

After an introduction explaining why there is any “problem” and why it is “inverse”, we will propose a firm probabilistic basis for inverse problems.

The usual ingredients of an inverse problem will be introduced (a priori information, theory, data), and it will be explained why nonlinearity is so capital.

Before introducing “methods of resolution”, considerable space will be used to clarify the conceptual frame (which is quite often misunderstood).

Crude methods, like trial and error or Monte Carlo will be introduced, and the principal formulas for deterministic inversion (optimization methods) will be given.

In the CDROM part, Monte Carlo methods will be described in detail, and the formulas for deterministic inversion will be demonstrated, both for discrete problems and for problems involving functions. Depending on the possibility of including good graphics, the methods will be illustrated (with seismological examples).

Table of Contents (simplified):

** Manuscript submission date: August 31, 1999.

(9/11/97)

Chapter 15. Seismic Data Acquisition, Processing, and Analysis

William H. K. Lee, U. S. Geological Survey, Menlo Park, CA, USA
and
Frank Scherbaum, Universitaet Potsdam, Potsdam, Germany

We attempt to provide a general review of seismic data acquisition, processing, and analysis for observing earthquakes. Our treatment will be based on the following chain of elements:

Source => Wave propagation => Instrument => Observation <==> Theory

We will concentrate on the output of "instrument" and try to infer information about each of the contributing elements: the classical "observation" and "theory" interactions. Because relevant theories and well established facts of earthquake seismology are treated in other chapters of this Handbook, we will emphasize useful methods and techniques in observing earthquakes. Due to page limitations, this chapter will be highly condensed. However, detailed explanations of some methods and techniques will be provided in the attached CD-ROM.

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** Manuscript submission date: February 28, 1999.

(Revised 3/31/98)

Chapter 16. Seismometry

Erhard Wielandt
Stuttgart University, Stuttgart, Germany

Emphasis: Understanding of modern broad-band, feedback seismometers, conditions for adequate recording, and relevant test procedures.

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** Manuscript submission date: October 1998, hopefully.

(7/31/97)

Chapter 17. Seismic Noise on Land and on the Seafloor

Spahr C. Webb
University of California at San Diego, La Jolla, CA , USA

After an introduction, I will start with the physics of noise sources and then go on to discuss the practical implications.

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** Manuscript submission date: February 28, 1999

(3/26/98)

Chapter 18. Digital Global Seismograph Networks

C. R. Hutt, K. Anderson*, R. Butler**, and R. Woodward**

**Albuquerque Seismological Laboratory, Abuquerque, NM, USA*
*** IRIS, Washington, D.C., USA*

This chapter will briefly review the HGLP, SRO, ASRO, and DWWSSN stations (for historical reasons only), as well as the IRIS GSN and other modern digital networks such as MEDNET & GEOSCOPE, for example. We will plan to put whatever detailed material we can get on all networks into the CDROM appendices.

Table of Contents (Tentative)

** Manuscript submission date: August, 1998.

(7/30/97)

Chapter 19.

Seismometer Arrays: Their Use in Earthquake and Test Ban Seismology

A. Douglas
AWE Blacknest, Nr Reading, United Kingdom

The use of seismometer arrays for the verification of a ban on nuclear tests appears to have been first suggested in early 1958 when Press (April) & Romney (May) in their replies to the questionnaire from the Disarmament Sub-committee of Congress both mentioned arrays of short-period (SP) seismographs. The Conference of Experts that met in Geneva in July-August 1958 to consider the technical problems of verifying a test ban also recommended the use of arrays.

One of the conclusions of the Experts Conference was that the first motion of P would be one of the main criteria for source identification. Thus observations of a clear negative first motion would identify the source as an earthquake. To confidently observe first motion however, requires the onset of the signal to be clearly seen above the noise and as P signals from earthquakes with magnitudes equivalent to those of underground explosions of a few kilotons would at many stations have amplitudes close to the noise level, some way was required to enhance the signal relative to the noise. The use of arrays appeared to be one such way.

The first arrays for the study of test ban verification were installed in 1960-62. The arrays had apertures of 3-4 kms, up to 16 seismometers, and were designed to record SP P signals from sources at regional distances. The aperture of these arrays is less than the wavelength of the signal of interest and initially the processing scheme was simply to sum the signals without time shifts. Such processing enhances signals with high apparent-surface-speeds and suppresses low-speed noise. These early studies showed that arrays could be used to extract signals from noise and in the following 5 years there was rapid development in array design and processing. The arrays of 3 kms aperture became known as small aperture arrays and several medium aperture (25 kms) and a large (200 km) aperture array were installed with the large array comprising initially 525 seismometers. The medium and large aperture arrays were designed for detecting SP P at teleseismic distances. Processing methods also developed rapidly. The most widely used method was delay-and-sum where the signals are time shifted to compensate for the travel time of the signal across the array and the signals are summed with weights 1/n. n is the number of seismometers in the array.

Comparison of the results from the arrays of different apertures suggest that the optimum aperture at least for SP signals with frequencies of about 1 Hz is about 25 kms. At larger apertures the signal is not coherent across the whole array and so the expected increase in signal-to-noise ratio is not achieved.

In recent years interest in using arrays for test ban verification has returned to the detection of signals at regional distances with frequencies above 1 Hz. Consequently there has been a revival of interest in small aperture arrays. For these small arrays and most other arrays currently in operation the main processing method remains delay-and-sum although recent work suggests that optimum multichannel filtering can give significant improvements in signal-to-noise ratio over these simple methods.

Although arrays were installed primarily to allow weak signals to be extracted from noise they do have applications in seismology generally. For example, arrays have been used: (1) to measure the apparent velocities and hence the slope of travel time curves to improve the detailed knowledge of earth structure; (2) to measure azimuths and apparent speeds of supplementary phases to help with their identification; and (3) to allow broadband estimates to be obtained of signals which on SP instruments have adequate signal-to-noise ratio.

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** Manuscript submission date: December 1998.

(7/21/97)

Chapter 20. Seismological Methods of Monitoring Compliance with the Comprehensive Test Ban Treaty

Paul G. Richards
Lamont-Doherty Earth Observatory, Palisades, NY, USA

Brief history of the previous test ban treaties and the CTBT, and associated technical challenges for monitoring. Different views, on how well the CTBT should be monitored. Perceptions as to the likelihood of various evasion scenarios, will drive assessments of the adequacy of monitoring capability of different networks.

General aspects of CTBT monitoring. This Treaty will in practice be monitored in three ways: by a new international organization (the IMS and the IDC working within the CTBTO); by national organizations that are given specific responsibilities in different countries; and by numerous other national and private organizations that may acquire and/or analyse data of relevance. Describe IMS and IDC plans and status at time of going to press with the book. (IMS and IDC are to provide data and basic data processing, and will carry out specific processing to assist States in the work of discrimination -- but assessments of compliance are left to the individual States.) Will the IMS data be openly available for uses other than CTBT monitoring?

The basic technical steps in monitoring the CTBT (detection of signal, association of signals, event location, and identification of seismic sources). Comment on the capabilities of the prototype IDC. Pay particular attention to the location problem, and how it matters in terms of CTBT language and the possibility of On-Site Inspection. Distinguish between routine processing, and what might be done for problem events. Examples of problem events.

Review evasion scenarios, and possible problems associated with the occurrence of numerous large chemical explosions in the mining and construction industries and in military programs.

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** Manuscript submission date: Since my subject is one that could change in important ways over the next few years, I'd like to submit as late as possible: summer 1999.

(7/31/97)

Chapter 21. The Structure and Interpretation of Seismograms

Ota Kulhanek
University of Uppsala, Uppsala, Sweden

The chapter will comprise a brief description of the composition (structure) of seismograms and a more extensive section with seismogram examples and corresponding interpretations.

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** Manuscript submission date: February 28, 1999

(11/4/97)

Chapter 22. Volcano Seismology

Stephen R. McNutt and John P. Benoit
University of Alaska, Fairbanks, AK, USA

This chapter will cover definitions, case studies, current concepts and problems, and state-of-the-art of forecasting eruptions and characterizing eruptions in progress. We plan to include a database of volcanic earthquake swarms for the accompanying CD.

<u>Table of Contents</u>

** Manuscript submission date: fall, 1998.

(Revised 2/3/98)

Chapter 23. Imaging the Three-Dimensional Structure and Magmatic Sources beneath Active Volcanoes

Harley M. Benz, U. S. Geological Survey, Denver, CO, USA
Robert B. Smith, University of Utah, Salt Lake City, UT, USA
and
Paul Okubo, Hawaiian Volcano Observatory, HI, USA

This chapter is intended to complement the general review of volcano seismology by McNutt and Benoit (Chapter 22). We will concentrate on the recent advances on tomographic imaging of volcano processes: a review of the methodology and a summary of results from several well-instrumented volcanoes.

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** Manuscript submission date: February, 1999.

(3/29/98)

Chapter 24. Marine Seismology

Kiyoshi Suyehiro and Kimihiro Mochizuki
The University of Tokyo, Tokyo, Japan

As the Section is planned, we will summarize established seismological facts, observational methods, and data analysis methods applied to marine seismic data. Focus will be on facts revealed exclusively by marine seismological surveys and on methods specific to marine data.

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1. Introduction

2. History

3. Seismological structures
   (a) Plate boundaries
   (b) Plate interior
   (c) Passive margins
   (d) Bathymetric highs
   [I wish to synthesize with seismicity description]

4. Marine seismic instrumentations
   (a) Past
   (b) Present
   (c) Future
   [These would help data users understand limitations in data quality or accuracy.]

5. Data analyses
   (a) structure (elastic/anelastic/anisotropic/reflectors and scatterers)
   (b) earthquake mechanisms

6. Summary

** Manuscript submission date: February, 1999.

(11/29/97)

Chapter 25. Tsunamis

Kenji Satake
Geological Survey of Japan, Tsukuba, Japan

I try to summarize basic and useful knowledge of tsunamis to seismologists. The emphasis will be given to seismological aspects of tsunamis, such as quantification of tsunamis, tsunami generation process and tsunami warning systems. Considering the fact that tsunami numerical computations have become popular in recent years, its background including some hydrodynamic basics will be also discussed.

Table of Contents (tentative)

** Manuscript submission date: first draft by the end of 1998.

(8/11/97)

Chapter 26. Earthquake Geology

Richard H. Sibson
University of Otago, Dunedin, New Zealand

Earthquakes are a fundamental part of geological process and leave an imprint in many parts of the rock record - for example, fault/fracture systems, the microstructural character of fault rocks, landforms, and styles of sedimentation. Conversely, the rock record contains much information relating directly to the character of the shallow earthquake source. This chapter therefore seeks to place shallow crustal earthquakes in their geological setting. Particular emphasis will be placed on the differing characteristics of the three dominant modes of faulting - thrust, strike-slip and normal fault systems - in relation to: (i) the geometrical and rheological structure of crustal fault zones at different crustal levels pertaining to the distribution of shallow crustal earthquakes and to source mechanics in both continental and oceanic crust; and (ii) a review of the role of earthquake activity in related geological processes including landform evolution, mass movement and sedimentation, and fluid redistribution in the crust. The related, rapidly expanding discipline of paleoseismology (the analysis of Quaternary fault displacement) has become of such enormous importance to earthquake hazard assessment that it is treated separately in the following chapter.

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** Manuscript submission date: July 30th, 1999.

(Revised 2/5/98)

Chapter 27. Paleoseismology

David P. Schwartz, U. S. Geological Survey, Menlo Park, CA, USA
Daniela Pantosti, Istituto Nazionale di Geofisica, Rome, Italy
and
Koji Okumura, Hiroshima University, Hiroshima, Japan

The chapter will emphasize a) the identification and dating of individual past earthquakes in the geologic record and b) techniques to measure thd amount of displacement per event and fault slip rates. The chapter will show how these paleoseismological data are used to develop earthquake recurrence models and estimates of seismic hazard. Numerous examples in the form of maps, trench logs and photographs of historical surface ruptures and actual paleoseismological case studies will be placed on the CD.

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** Manuscript submission date: February 28, 1999.

(1/14/98)

Chapter 28. Using Earthquakes for Tectonic Geology

James A. Jackson
University of Cambridge, Cambridge, UK

Seismology contributes to tectonic and structural geology mostly through earthquake source studies. These allow a detailed knowledge of how faults move while they are active. This is potentially an enormous advantage over classical structural geology, which looks at inactive structures, as these old features can change orientation through uplift, rotation, tilting, etc. In addition, we can look at patterns of active faulting over wide regions, knowing they are simultaneously active (which is very difficult to prove for old structures), and there are some features of faults (like slip vectors, precise physical dimensions) which are almost impossible to get from inactive structures.

It wasn't until synthetic seismogram techniques became routine and accurate that earthquake source dimensions could be determined accurately enough to influence geological debate. That occurred in the early 1980s and has had a profound impact. I will then address the most important structural results that come out of use of earthquake source studies:

* Focal depths. Including the seismic/aseismic transition, the scale imposed by the seismogenic thickness, and the notion of big vs. little faults.

* Fault dips. Including controversies surrounding high- vs. low-angle faulting in extension and shorting, listric vs. planar faults, basement vs. thin-skinned deformations

* Slip vectors. Their role in understanding rotations and partitioning of oblique motion.

* Scaling and size. Including how faults grow.

* Use of fault populations. Including measurement of strain and velocity fields.

* Large-scale continental tectonics. A summary of the insight from earthquakes into how continents deform at a very large scale (e.g. Asia, the Middle East, the Mediterranean).

** Manuscript submission date: August 31, 1999.

(8/4/97)

Chapter 29. Rock Failure and Earthquakes

D. A. Lockner
U.S. Geological Survey, Menlo Park, CA, USA

This chapter is intended to present well-established observational facts and accepted theory of rock failure and friction that are relevant to the study of earthquakes. Mohr-Coulomb theory and Griffith cracks will be introduced and then built upon to trace the development of Continuum and Damage Mechanics theories as well as SOC models. Laboratory studies of microcrack growth, acoustic emission, shear zones and fault microstructure will be discussed. Leading theories of friction and how friction is related to rock strength will be discussed. A summary of laboratory observations of frictional properties (shear strength and its dependence on displacement, slip rate, mineralogy, water content, temperature) as well as strength recovery and fault healing will be presented. State of stress in the crust will be discussed in the context of laboratory rock strength and friction; including the possible role of fluids and mineralogy. If not covered in other chapters, a review of representative earthquake models will be made in the context of accepted fracture and friction theory. The various factors known to affect rock strength and friction will be discussed. A quick reference compilation of rock strength and friction for various minerals/rocks will be assembled.

Table of Contents (provisional)

** Manuscript submission date: February, 1999.

(11/21/97)

Chapter 30. The State of Stress within the Earth

Larry Ruff
University of Michigan, Ann Arbor, MI, USA

Looking through the list of topics, there is no other paper that will directly discuss the stress state within the Earth, so it seems that my contribution should touch on all aspects of stress -- even briefly upon the hydrostatic stress state (though not a current research topic). Since there are several other papers that discuss relevant aspects of earthquake mechanics (especially Jim Brune's paper), I do not need to spend a lot of time on that -- I will just try to use the overall results from earthquake stress drop estimates.

My tentative plan is to touch upon all the various ways that people have tried to infer stresses within the earth, i.e. a much broader spectrum than just the earthquake aspect. Of course, it will be a challenge to follow this broad spectrum approach AND stay within the 15 page limit.

Table of Contents

1. Introduction
   Fundamental importance of stress
   Basic definition: hydrostatic stress shear stress (notion of time, i.e. static to dynamic)
   Short history

2. Hydrostatic Stress in Earth
   Classic determination of pressure within Earth
   Modern models all agree for gross Earth values
   Regional variations & isostasy

3. Shear Stress
   Introduction to methods of determination
   So-called direct measurements (boreholes & mines)
      rock mechanic estimates
   Topography & stresses (classic Jeffreys argament)
      seamounts, ice, and so on
   Earthquakes: static stress drops as lower bounds
   Earthquakes: Notions of fault friction & shear stress
      are static stress drops full or partial?
   Frictional heating at plate boundaries (strike-slip)
   Shear stress at subduction zones (EQs & friction heating)
   Plate tectonics & shear stresses (global force balance & such)
   Summary of above
4. Concluding remarks and future directions

** Manuscript submission date: early summer, 1998.

(7/31/97)

Chapter 31. Tectonic Stress in the Earth's Crust

Mark D. Zoback, Stanford University, Stanford, CA, USA
and
Mary Lou Zoback, U. S. Geological Survey, Menlo Park, CA, USA

This chapter will be a review of a variety of publications on the state of stress in the earth's crust. Emphasis will be on techniques to measure both the orientation and magnitude of tectonic stress and on large-scale intraplate stress patterns. Relationship between stress and seismicity will be briefly discussed.

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** Manuscript submission date: Feb. 28, 1999

(5/16/98)

Chapter 32. Strength and Energetics of Active Fault Zones

James N. Brune, University of Nevada, Reno, NV, USA
and
Wayne Thatcher, U. S. Geological Survey, Menlo Park, CA, USA

The strength of active fault zones, i.e., the stress levels required to produce earthquake ruptures, is obviously one of the most fundamental properties required to understand the physics of earthquakes, and thus to have a solid basis for understanding earthquake hazard, In spite of thirty years of dedicated research, fault strength remains uncertain by an order of magnitude. Although many researchers have concluded that fault zones are weak (100 bars or less), others maintain that they are strong (of the order of a kilobar).

The data are apparently inadequate to be completely convincing, In part this stems from the fact that the main source of energy release in earthquakes is at depths greater than 5 kilometers, depths relatively inaccessible to direct instrumental observation (very expensive deep drilling in fault zones is currently being proposed). Another factor limiting resolution is the fact that seismic waves arriving at the surface from earthquakes are nearly linear perturbations of the absolute stress field, and thus an unknown absolute static background stress (unknown), can be added to stress models without changing the basic characteristics of the observed waves and geodetic deformations.

The fundamental energy changes produced by earthquakes are seismic energy and frictional heat, energy (other energy sinks and sources have been proposed). Unknown physical factors that might help to reduce the uncertainties if better understood include the role of fluid pressure on fault zones, dynamic inertial effects during rupture (most models of faulting are quasi-kinematic), and rotational degrees of freedom in the fault zone. Attempts at modeling earthquakes have included sophisticated computer models, models using small rock samples, and models using analog materials such as polyurethane and plastics. This chapter discusses all of the available evidence and current ideas about fault zone strength and energetics.

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** Manuscript submitted date: August, 1998.

(8/21/97)

Chapter 33. Earthquake Strain, Near-Silent Earthquakes and Nucleation

Malcolm J. S. Johnston, U. S. Geological Survey, Menlo Park, CA, USA
and
Alan T. Linde, Carnegie Institution of Washington, Washington, DC, USA

Fault failure occurs seismically and aseismically. High precision strain measurements in boreholes near active faults record the transients in crustal deformation generated by the failure process typically at the nanostrain level over periods from milliseconds to months. These transients reveal details of the fault failure process, the earthquake nucleation process, the stress/strain redistribution following failure, and variation in material properties of fault zone materials.

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** Manuscript submission date: January, 1999.

(Revised 2/19/98)

Chapter 34. Measurement of Coseismic Deformation by Satellite Geodesy

Kurt Feigl
CNRS, Toulouse, France

1. Brief Summary of Applicable Techniques: Geometry, software, calibration, requirements, advantages, disadvantages
   - 1.1. History: ground-based techniques
   - 1.2. SF 1906, Reid & Bowie
   - 1.3. Japan?
   - 1.4. others?
   - 1.5. VLBI
   - 1.6. SLR?
   - 1.7. GPS
   - 1.8. SAR interferometry

2. Estimating Earthquake Parameters by Inversion of Geodetic Data
   - 2.1. Hierarchy of inverse problems
   - 2.2. Elastic modeling
   - 2.3. Surface displacement
   - 2.4 Moment
   - 2.5. Fault slip
   - 2.6. Focal mechanism
   - 2.7. Data covariance matrix?

3. Case Studies

Focus on events recorded by two or more techniques: Will require at least one 4-panel color figure per case study. This to show observed, modeled, residual, interpreted interferograms. At 16 panels per page, this implies 4 pages of color. This section will involve reprinting many previously published figures, as well as some text recycled from an article by Massonnet and Feigl for Reviews of Geophysics, scheduled for publication in 1998.

   - 3.1. Landers, CA
   - 3.2. Northridge, CA
   - 3.3. Kobe, Japan
   - 3.4. Eureka Valley, CA
   - 3.5. Avoca River, NZ
   - 3.6. Grevena, Greece
   - 3.7. Antofogasta, Chile
   - 3.8. Aigion, Greece
   - 3.9. Other 1
   - 3.10. Other 2
   - 3.11. Other 3
   - 3.12. Other 4

4. Synthesis and Conclusion
   - 4.1 Scaling?
   - 4.2 Geodetic versus seismological estimates of moment
   - 4.3 Utility for assessing seismic risk?
   - 4.4 Future prospects

5. Reference list
   - 5.1 As complete as possible.
   - 5.2 Papers published in refereed journals only.
   - 5.3 No proceedings!

6. Not included because too speculative for a Handbook on Earthquakes?
   - 6.1 Slow earthquakes by geodesy
   - 6.2 Slow deformation such as interseismic, postseismic, or creep
   - 6.3 Combinations of earthquakes and volcanoes, e.g., Iceland or Afar

** Manuscript submission date: February 28, 1999.

(2/19/98)

Chapter 35. Electromagnetic Fields Generated by Earthquakes

Malcolm J. S. Johnston
U. S. Geological Survey, Menlo Park, CA, USA

Magnetic, electric and electromagnetic field variations are generated by seismic events and tectonic stress/strain loading. The observed coseismic offsets are instantaneous and relate generally to the seismic source. Longer term changes relate to crustal deformation, with contributions from fluid movement in the crust and induced fields from ionospheric disturbances convolved with changing crustal conductivity. Simple piezomagnetic dislocation models based on geodetically and seismically determined fault parameters generally match the observed coseismic signals in size and sign. Electrokinetic effects resulting from rupture of fluid filled compartments at hydrostatic to lithostatic pore pressures can generate transient signals in the frequency band 100 Hz to 0.01 Hz. However, large-scale fluid driven processes are not evident in near-field measurements in the epicentral region minutes to weeks before large earthquakes. The subset of ionospheric disturbances generated by trapped atmospheric pressure waves (also termed gravity waves and/or acoustic waves, traveling ionospheric disturbances or TID's) that are excited by earthquakes and volcanic eruptions are common and propagate to great distances. These are known and expected consequences of earthquakes and volcanic explosions, that must be identified and their effects removed from VLF/ULF electromagnetic field records before associating new observations of ionospheric disturbances with earthquake activity.

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** Manuscript submission date: January, 1999.

(1/12/98)

Chapter 36. Fluid Migration in the Crust and Its Relation to Earthquakes

George Igarashi and Chi-Yu King
The University of Tokyo, Tokyo, Japan

We summarize the present understanding of the origin and transport mechanisms of fluids in the Earth's crust. We focus on the roles of the crustal fluids in controlling the stress and strain distribution in the deep crust and their relation to the nucleation process of earthquakes. Then we evaluate the usefulness of geochemical and hydrological observations in detecting premonitory phenomena for the purpose of earthquake prediction.

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** Manuscript submission date: August 31, 1998.

(2/5/98)

Chapter 37. Case Histories of Triggered and Induced Seismicity

Art McGarr, U. S. Geological Survey, Menlo Park, CA, USA
and
David W. Simpson, IRIS, Washington, DC, USA

After a general introduction describing the important problem areas in triggered and induced seismicity, the chapter will use a series of case histories to exemplify these critical questions. The case histories will involve earthquake due to hard-rock mining, quarry operations, liquid injection at depth, compaction of oil and gas reservoirs due to production, reservoir impoundment, large midcrustal earthquakes due to large-scale hydrocarbon exploitation, and finally the effects of natural earthquakes on the regional seismicity.

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** Manuscript submission date: January, 1999.

(7/23/97)

Chapter 38. A Global Earthquake Database: 1900-1999

E. R. Engdahl and Antonio Villasenor
U. S. Geological Survey, Denver, CO, USA

This Chapter describes the construction of a comprehensive catalog of all globally detected earthquakes during the 20th century. Seismicity data spanning long periods of time are essential for a thorough understanding of the earthquake phenomenon. However, earthquake locations during this century are largely non-uniform and for most earthquakes occurring prior to about 1964 are poorly determined, simply because modern data analysis techniques have yet to be applied to the available arrival-time observations. Assembly of the global database is a multi-stage process. First, we combine all existing digital catalogs of earthquake locations and magnitudes for the century (primarily compilations by Gutenberg and Richter, ISS, BCIS, ISC and NEIC). Second, we convert where necessary the available arrival-time data into a computer-ready digital format directly from the printed bulletins. Third, we relocate the entire database using improved travel times and procedures for depth determination. Finally, we cull from this massive database all earthquakes which are globally detected or are otherwise tectonically significant, compiling in the process earthquake statistics in time such as completeness, moment release and recurrence rates, both globally and regionally.

Table of Contents (provisional)

There would follow (on CD-ROM) a comprehensive digital catalog of hypocenters, phase arrival times and magnitudes for all globally detected earthquakes during the 20th century, including a complete list of operating stations, with search and display software.

** Manuscript to be submitted: July, 1999

(3/4/98)

Chapter 39. Seismicity and Tectonics of the Earth

E. R. Engdahl, U. S. Geological Survey, Denver, CO, USA
and
Stephan H. Kirby, U. S. Geological Survey, Menlo Park, CA, USA

This is a survey of the seismicity of the Earth in the context of the large-scale tectonics of the globe. The characteristics of seismicity (location, size, mechanism, as well as their uncertainties) can be understood to a good approximation in terms of the plate tectonics hypothesis as put forth in the late 1960's. Substantial modifications of this hypothesis in the 1970's and early 1980's have resulted in significantly improved understanding of the seismotectonics of some areas, notably continental regions, that were not tractable with the simplest, rigid plate description of global tectonic processes. This chapter will synthesize observational results on the seismicity of the Earth for the 20th Century and interpret this seismicity in terms of current models of the tectonics of the Earth.

Table of Contents (provisional)

** Manuscript to be submitted: July, 1999

(Revised 3/4/98)

Chapter 40. Statistical Features of Seismicity

Tokuji Utsu, Tokyo, Japan

This chapter describes fundamental knowledge and some recent important achievements in the statistical study of seismicity. It does not include statistical techniques used in other fields of seismology, such as hypocenter determination, studies of earth structure, source process, crustal deformation, etc.

Table of Contents (tentative)

** Manuscript submission Date: December, 1998.

(6/22/97)

Chapter 41. Historica1 Seismicity and Tectonics

Nicholas N. Ambraseys, James A. Jackson**, and Charles P. Melville***
**Imperial College of Science, London, UK*
*** Cambridge University, Cambridge, UK*

The purpose of this chapter is to describe the use of historical evidence to answer two questions: why do earthquakes happen where and when they do? Why this century are some places frequently shaken, but other seldom?

As we cannot know what will happen in the future, we have to find out what happened in the past and extrapolate a little to the future. Previous research on earthquakes has uncovered evidence of destructive earthquakes in areas where only small events have been felt recently. This is not surprising: the time-scale of geology is vastly different than that of human history, so some areas will suffer a short period of violent earthquakes only once in a few hundred years. Thus, it follows that if our research on earthquakes used only the period of the past 100 years in which earthquakes have been recorded by instruments, then we would have no way of knowing whether or not a supposedly "quite" area is in fact at risk from a damaging earthquake. The use of the historical record is invaluable not only in the study of earthquakes but also of the climate and weather, and can guide the engineer to design structures to resist such forces of nature without surprises.

Most of the historical information for our study area covering the last 2,500 years comes from historians and chroniclers. Clearly for the information in historical sources, which are written in both dead and alive languages, to be usefu1 to modern science the sources must be subjected to a rigorous critical analysis: remove exaggerations and errors of date and location. If these sources tell us enough about earthquakes, using modern techniques we can estimate the size of these events and estimate their effects if they re-occur. In the same way, time intervals between destructive earthquakes in a certain place help us to establish a pattern for their occurrence, and establish the long-term seismicity in that place.

The use of long-term seismicity, which can only be assessed from an inter-disciplinary study, gives a far better understanding of earthquake hazard, because it will be based on human experience of earthquakes over a much grater range of the geological time-scale of 2,500 years against the mere 100 yeas of instrumental records.

The results from such a study are invaluable in planning, social and economic development and minimize the risk of great human and economic losses.

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** Manuscript Submission Date: December 31, 1998.

(1/20/98)

Chapter 42. Historical Earthquakes and Their Impacts to Societies

Amos Nur
Stanford University, Stanford, CA, USA

Although earthquakes have often been associated with inexplicable past societal disasters their impact has thought to be only secondary for two reasons: Inconclusive archaeological interpretation of excavated destruction, and misconcepts about patterns of seismicity. However, a better understanding of the irregularities of the time-space patterns of large earthquakes suggest that earthquakes (and associated tsunamis) have probably been responsible for some of the great and enigmatic catastrophes in ancient times.

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5. Jericho and the earthquake of 31 BC

6. Slip Deficit and Earthquake Sequences.

7. Implications
    (1) Why so many ruins revisited
    (2) Past antiseismic construction
    (3) Earthquakes, assailability and collapse of cultures
        Hatussa
        Jericho
        Crete

** Manuscript submission date: August 31, 1999.

(8/14/97)

Chapter 43. Historical Earthquakes of Selected Regions of the World

We define "historical" earthquakes in a given region as events that occurred prior to adequate seismic instrumentation, so that earthquake parameters are primarily estimated from damages caused by the earthquakes. In many regions of the world, the period of historical earthquakes began when human records of earthquakes first existed (e.g., about 1831 B. C. in China) and onto the modern days when seismic instruments are adequate (e.g., to about 1960). The time period for a given region is thus dependent on the available historical records. The completeness of historical earthquakes (to a cutoff magnitude, say, 6) is often in question. Nevertheless, when historical earthquakes are properly documented and interpreted, they are valuable in assessing the earthquake risk of a region, because adequate seismic instrumentation is seldom more than 50 years.

This chapter will have several sub-chapters. We welcome suggestions and comments. Very tentative sub-chapters are:

43.1 Historical earthquakes of California (T. Toppozada).
43.2 Historical earthquakes of China (Y. S. Xie)
43.3 Historical earthquakes of Greece (B. C. Papazachos).
43.4 Historical earthquakes of India (S. P. Satyabala)
43.5 Historical earthquakes of Italy (?).
43.6 Historical earthquakes of Japan (T. Usami)
43.7 Historical earthquakes of South America (J. S. Carmona)

(6/15/98)

NOTE: Available sub-chapter outlines are shown below:

Chapter 43.1 Earthquake History of California.

T. R. Toppozada and others.
California Division of Mines and Geology, Sacramento, CA, USA

This chapter will contain description of California earthquakes of M.5.5 (or 6) from 1769, with emphasis on pre-instrumental events, giving estimates of epicenter and M, and comparison to modern instrumentally-defined events.

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** Manuscript submission date: February 28 1999 or more likely August 31 1999.

(5/8/98)

Chapter 43.4 Historical Earthquakes of India

S.P.Satyabala
National Geophysical Research Institute, Hyderabad, India

The time period that the manuscript will cover is approximately 1800 to 1950 AD and perhaps some earlier events. The approximate geographic region is the whole of India including the Himalaya and North-East India.

** Manuscript submission date: March 1999 (June 1999 for the data).

(4/15/98)

Chapter 44. Seismicity of selected Regions of the World

*** This Chapter is being organized now. ***

Chapter 45. Seismic Structure of the Continental Crust and Uppermost Mantle

Claus Prodehl, *Geophysical Institute, University of Karlsruhe, Karlsruhe, Germany,*
Walter D. Mooney, *U. S. Geological Survey, Menlo Park, CA, USA,*
Nina I. Pavlenkova , *Institute of Dhysics of the Earth, Moscow, Russia,*
Rong ShengZeng, *State Seismological Bureau, Beijing, China*

In the introduction, the chapter will list the most important methods of interpretation of explosion-seismic data. The main part of the chapter will deal with the P-wave structure velocity structure of the continental crust and uppermost mantle and, where available, S-wave velocity information. We will show contour maps and cross sections sampling the most characteristic features of each continent. The closing chapter will compare the characteristic worldwide main features of the equivalent main geological units. Because of the immense wealth of publications on this subject we will reference mainly summary papers only.

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** Manuscript submission date: February, 1999.

(Revised 3/9/98)

Chapter 46. Seismic Structure of the Oceanic Crust and Upper Mantle

Tim A. Minshull
University of Cambridge, Cambridge, UK

The chapter will cover the P- and S-wave velocity structure of the oceanic crust and mantle lithosphere, how these have been determined and how they vary with age and tectonic setting. A section on the mantle lithosphere will cover lithospheric thickening with age, and perturbations to the seismic structure by hotspots. The seismic structure of oceanic crust at mid-ocean ridges, fracture zones, aseismic ridges, ocean islands, and passive margins will be contrasted with that of "normal" oceanic crust in ocean basins. Spreading-rate-dependent variations in oceanic crustal structure will also be covered. The emphasis will be on observations rather than geological interpretation, but widely accepted interpretations will be summarised. Experimental methodologies used to determine oceanic crustal and upper mantle structure will also be summarised.

Table of Contents (provisional)

** Manuscript submission date: February 28, 1999

(11/25/97)

Chapter 47. The Earth's Interior

Thorne Lay
University of California, Santa Cruz, CA, USA

This chapter will review the basic structure of planet Earth, as deduced from seismology, geophysics and geochemistry. It will emphasize the first-order layered structure of the Earth, along with summarizing current understanding of three-dimensional structure derived from the methods of Geophysical Inversion (Chapter 8), Synthetic Seismograms (Chapters 4 & 5), Seismic Anisotropy (Chapter 39) and Seismic Tomography (Chapter 40). The emphasis will be on the deep Earth, with only minor discussion of the complexity of the Earth's crust (Chapters 36 & 37).

The importance of understanding Earth structure for the analysis of earthquake generated vibrations will be discussed, along with the nature of trade-offs in our understanding of earthquake parameters and Earth structure. Anelasticity of the interior will be reviewed, along with discussion of the effects on earthquake vibrations. The perspective of the Earth's interior as a large-scale dynamic system driven by planetary cooling and ultimately responsible for the Tectonic processes (Chapter 30) that produce earthquakes will be developed. Current frontiers in deep Earth research will be noted.

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** Manuscript submission date: August, 1999.

(8/7/97)

Chapter 48. Seismic Anisotropy

Michel Cara
Laboratoire de sismologie, EOST, Strasbourg, France

Once believed as restricted to the crust or the uppermost part of the mantle - if not a pure artifact - seismic anisotropy has become an increasing evidence for many seismologists. During the past two decades, the number of paper published on the subject has grown dramatically. Accepting anisotropy in seismological models makes the theory much more tricky and, unfortunately, the number of parameters to be resolved are in general too large for an unambiguous interpretation of a given set of seismograms.

There are circumstances, however, where simple and unambiguous observations can bear extremely valuable informations on how forces act in the Earth : examples are local earthquake S-wave splitting indicating alignment of cracks due to seismogenetic stresses; teleseismic S waves and surface wave anomalies indicating coherent preferred orientation of crystals in the subcrustal lithosphere and/or asthenosphere. Taking example in the literature, emphasis will be made on examples where seismic anisotropy makes the physical models of the structure and/or the source more simple than isotropic models aimed at explaining the same set of seismograms.

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** Manuscript submission date: August 31 1998.

(7/30/97)

Chapter 49. Probing the Earth's Interior with Seismic Tomography

R. K. Snieder
Utrecht University, Utrecht, the Netherlands

Seismic tomography is an important tool for mapping the seismic velocity in the Earth's interior. This is used on a variety of different scales ranging from cross-borehole tomography to global tomography. A variety of different types at different frequencies have been used for this purpose. An overview will be given of the types of waves that are used and for seismic tomography and the major techniques for carrying out tomography will be outlined. A number of case studies will be presented as well as some recent advances in this field of research.

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** Manuscript submission date: February, 1999.

(Revised 2/17/98)

Chapter 50. Normal Modes of the Earth and Planets

Philippe Lognonné and Eric Clévédé
Institut de Physique du Globe de Paris, Saint Maur des Fosses, France

This chapter will present the history of normal modes observation, the development of the theory from the simple spherical earth model to the full aspherical anelastic rotating earth. Final part will present the inversions, and will open prospect on normal modes studies of other planets.

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** Manuscript submission date: February 28, 1999.

(1/21/98)

Chapter 51. Strong Ground Motions in Earthquakes

Thomas H. Heaton, California Institute of Technology, Pasadena, CA, USA
and
David J. Wald, U. S. Geological Survey, Pasadena, CA, USA

In this review, we will discuss some of the many phenomena that can determine the nature of strong ground motions in earthquakes. Some of these phenomena have been inferred from the study of existing ground motion records, and others are inferred from theoretical models of earthquake sources and wave propagation.

The subject will be broken into two main areas: 1) Effects due to wave propagation, and 2) effects due to the rupture process. The source section will be further divided into effects that can be modeled deterministically and effects that can only be modeled stochastically. There will be additional emphasis given to differences between ground motions from subduction zones versus ground motions from shallow crustal earthquakes. We may also discuss some aspects of estimating ground motions for intraplate earthquakes. There will be considerable emphasis on discussing the problem of estimating ground motions for large magnitude earthquakes.

Table of Contents

1. Introduction: discussing the wide variety of ground motions that can be experienced during earthquakes, even at a fixed magnitude and distance. There will also be some discussion of ways to parameterize earthquake ground motions.

2. Effects due to wave propagation: Propagation of waves in the crust. This section will discuss the general wave types encountered in crustal propagation of waves; P-waves, S-waves, Rayleigh Waves, Love waves, reflected waves, etc. Simple Examples will be shown to demonstrate how the crust affects wavetrains.

3. Near-site soils: This section will discuss resonances that can occur in soil columns with examples given for Mexico City and San Francisco. It will also discuss nonlinear effects in soils due to nonelastic yielding.

4. Basins: This sections will show how ground motions can be effected by the presence of geologic basins.

5. Topography: This section will discuss the importance of topography on ground motion amplitudes.

6. Fault zone guided waves: This section will demonstrate how low velocities in fault zones can sometimes influence wavetrains.

7. There will be a discussion of how wave propagation differs between stable cratons, the western US, and subduction zones.

8. Effects due the Rupture Process: There will be a general discussion of techniques for modeling the source of earthquakes, e.g. deterministic modeling, stochastic modeling, and Empirical Green's functions.

9. There will be a section on directivity with emphasis on near-source displacement pulses.

10. There will be a section on spatial heterogeneity of rupture and its importance to strong ground motions.

11. There will be a section on the effects of radiation pattern.

12. There will be a section on rupture scaling parameters, including stress drop, slip duration, and rupture dimensions.

13. There will a section on ground motions that may occur during very large magnitude earthquakes for which we have no recordings.

** Manuscript submission date: August, 1999.

(8/13/97)

Chapter 52. Site Effects on Strong Ground Motions

Hiroshi Kawase
ORI, Inc., Shimizu Corp., Tokyo, Japan

This chapter describes the state-of-the-art of site effects studies on seismic ground motions, especially during strong earthquakes. It covers theoretical aspects of site effect studies, which will start from one-dimensional amplification of surface soil layers and extend to the wave propagation within very complicated three-dimensional structures, as well as observational aspects of them, which include borehole measurements, horizontal array measurements, experimental methodologies, and so on. The importance of site effects are, however, lies in its direct consequence of the damage distributions during the past strong earthquakes such as Michoacan, Mexico earthquake, Northridge earthquake, and Kobe earthquake. Thus the site effect studies should be considered as one of the very important part of the whole strong motion prediction process. The reviews here will be performed under such basic concept. The importance of constructing underground structures for the site effect study should also be emphasized.

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Manuscript will be submitted: February 28, 1999.

(11/18/97)

Chapter 53. Use of Engineering Seismology and Geotechnical Engineering Tools in Ground Shaking Scenarios

Ezio Faccioli and Vera Pessina
Dipartimento di Ingegneria Strutturale, Politecnico di Milano, Milano, Italy

The focus is on the quantitative estimation of ground motions in the context of constructing damage scenarios for urban areas exposed to destructive earthquakes. The salient physical factors at play are examined, and their influence on the predictions both of building damage and geologic damage, e. g. slope failures, is also considered. In many parts of the world the local seismic hazard is governed by ill-known geologic features, which make it often impossible to apply advanced seismological modeling. Hence, emphasis is placed whenever possible on the use of simpler tools (e. g. empirical relations) that have been traditionally used by engineers. To give some quantitative insight, comparisons among the results of simplified and advanced methods, as well as of observations, are illustrated from recent real scenario studies.

The choice of possible ground motion descriptors is analyzed first, and such diverse parameters as peak acceleration, ordinates of elastic displacement spectrum, or Arias intensity are discussed, mainly in relation to the method used for estimating damage to structures and to the geologic environment.

Among the factors related with the earthquake source we consider the geometric representation in the case of extended sources and the directivity effects, of strong relevance when urban areas are located in the near-field, as shown by the Northridge (1994) and Kobe (1995) earthquakes. The feasibility of simplified approaches for including directivity is discussed.

As regards the evaluation of local amplification and site effects, we examine first the collection, interpretation and modeling of local geologic and geotechnical data for building a plausible subsoil model of the investigated area. The construction of geotechnical databases, and of appropriate geotechnical zonation maps derived therefrom, are dealt with in some detail because of the strong influence they can have on the predicted damage severity and distribution. Simplified methods of predicting site-dependent ground motion parameters are treated with emphasis on the inherent uncertainties attached to them, as may be evaluated through a comparison with alternative approaches based on observations, such as the empirical Green's function method. Another significant topic discussed is the feasibility of a simplified treatment of complex site effects, as may be related to topography or edges of alluvial basins. Significant duration of ground motions and nonlinearity of soil response are the final factor considered in connection with local amplification.

The discussion of the previous topics is illustrated with the aid of GIS-generated maps and specific examples, a few of which taken from the presently conducted project for a detailed earthquake damage scenario for the city of Catania (Southern Italy).

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Manuscript: submission date: February 28, 1999.

(12/1/97)

Chapter 54. Some Significant Strong-Motion Instrumentation Programs

Yi-Ben Tsai, National Central University, ChungLi, Taiwan,
Tzay-Chyn Shin, Central Weather Bureau, Taipei, Taiwan,
and
Ta-liang Teng, University of Southern California, Los Angeles, CA, USA

This chapter will review some significant strong motion instrumentation programs and their impacts on the advancement in earthquake and engineering seismology. Special emphasis will be placed on several significant old and recent programs undertaken in California, Japan and Taiwan. By reviewing these programs we also hope to trace the development of strong motion instrumentation from analog to digital ages. Several well known accelerograms of particular significance will be singled out for more detailed discussion. The chapter will cover strong motion instrumentation both in the free field and in structures. A brief summary of strong motion instrumentation programs of the world will also be presented. At the end we will discuss future prospects of some unconventional applications of strong motion instrumentation, such as for earthquake early warning and rapid response of large earthquakes.

Table of Content (tentative)

Manuscript submission date: August 31, 1998

(8/14/97)

Chapter 55. Kyoshin-Net (K-Net)

Shigeo Kinoshita
National Research Institute for Earth Science and Disaster Prevention, Tsukuba, Japan

Kyoshin Net (K-NET) is a system which sends strong-motion data on the Internet, data which are obtained from 1,000 observation stations deployed all over Japan. The K-NET was constructed by National Research Institute for Earth Science and Disaster Prevention (NIED) in 1996 after the Kobe Earthquake of 1995, in ord`r to get strong-motion data in hypocentral areas and to distribute these data as soon as possible. As the average ctation to station distance of K-NET sites is about 25 km, the K-NET can sample the epicentral region of an earthquake with a magnitude of 7 anywhere in Japan. The strong-motion seismograph, type K-NET95, which is used in the K-NET, has a recording system with a 24-bit A/D converter. This recording system retains the causality of original acceleration signals from 3-component seismometer.

The K-NET makes three kinds of data files, UNIX, DOS, and ASCII files, with a common header including a prompt source parameters determined by Japan Meteorological Agency, and provides these files on the Internet. The Internet addresses of K-NET control center and two mirror sites are as follows:

http://www.k-net.bosai.go.jp
http://www.k-net.ostec.or.jp
http://www.k-net.geophys.tohoku.ac.jp

In addition to strong-motion data, the K-NET provides the soil information of K-NET station sites including P- and S-wave data obtained by a downhole method. The map of maximum acceleration is available on the Internet when the K-NET has recovered enough data. This K-NET information is also obtained from the K-NET FTP sites by changing the header part of Internet address from http to ftp.

From April 1, 1997, utility programs for the K-NET DOS files have been released on the Internet. The released programs are able to calculate and plot velocity and displacement seismograms in addition to the plotting of original acceleration seismogram. The utility programs can also calculate Fourier, power, energy and response spectra. Plotting programs for the calculated spectra are included in the utility programs.

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** Manuscript Submission Date: September 30, 1998

(11/13/97)

Chapter 56. Strong-Motion Data Processing

Anthony F. Shakal, Moh-Jiann Huang and Vladimir Graizer
CSMIP, California Division of Mines and Geology, Sacramento, CA, USA

This chapter will provide a technical review of central aspects of strong-motion data processing. It will include a review of the evolution of processing, its current application, and the inherent limitations.

The processing of strong-motion data has seen significant evolution and development in the last few decades. One important step was the technical advances and standardization that occurred during the Caltech digitization and processing project following the 1971 San Fernando earthquake. Prior to this project, digitization and processing using digital computers had few standards and many methods were used. An analog processing effort in the 1950s was important in establishing the limits of what could be accomplished without digital computers.

In the decades since the San Fernando earthquake and the Caltech project there have been major advances in the level of automation of processing, as well as advances made possible by the advancement in the instruments themselves. In its most modern realization, the processing of many records can be accomplished, at least in a preliminary mode, in a totally automated manner. This approach, called near-real-time processing, portends the future, as more of the installed base of instruments become digital, with communication capability. Distribution of data via the Internet is another recent step that increases user convenience.

The most effective means of presenting processed data has also evolved. The presentation of the digitized results is important, and the background of current methods used will be presented.

Regardless of technological state, from early analog computer attempts through the Caltech Bluebook project through the most modern near-real-time approaches, one fundamental issue carries forward in common. Strong-motion records are a combination of signal and noise. As a result, processed data has a certain bandwidth, or range of periods/frequencies, within which the data can be used with confidence, and outside of which noise is dominant. This reliable period range, or Usable Data Bandwidth, is one of the most important aspects that users of strong-motion data must understand to make the most effective use of data. The limitations at long period arise from limitations at the sensor level, and in the case of analog recorders, the digitization system used.

The chapter will include a review and comparison of the processing methods used by the primary sources of strong-motion data, in Japan, New Zealand and Italy, as well as California and the USGS. Their commonalities will be underscored.

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3. Standard Presentation of Processed Results
    A. Acceleration, velocity and displacement time series
    B. Response and Fourier amplitude spectra
    C. Data format
    D. Near-real-time data
4. Long period noise and the Usable Data Bandwidth
    A. Origin and characteristics of noise
        (i) Analog accelerographs, film and digitization origins
        (ii) Digital accelerographs, electronic and sensor noise
    B. Methods of limiting the effects of long period noise
    C. Use of data in the Usable Data Bandwidth

5. Strong Motion Processing Commonalties by Major Networks (Japan, Italy, New Zealand, U.S.)

6. Conclusions

7. References

**Manuscript submission date: February 28, 1999.

(Revised 2/26/98)

Chapter 57. Dynamics of Earthquake Response

Paul C. Jennings
California Institute of Technology, Pasadena, CA, USA

This chapter will provide a technical introduction to the dynamics of earthquake response and the tools of analysis used in analysis and design of earthquake resistant structures. The emphasis will be on the presentation of response spectrum methods and other methods of linear analysis and their application in the design process.

The chapter will begin with a discussion of the important engineering characteristics of strong earthquake excitation and of the inventory of strong motion records. The discussion will include examination of the amplitude, frequency content and duration of shaking, as well as the different characteristics of near-field and far-field motions. Examples of important records will be included.

The chapter will next present a description of the different types of structural response to earthquake motions, ranging from linear response, through ductile response and up to failure and collapse. This portion of the chapter will be illustrated with recorded motions of structures and photographs illustrating earthquake response.

The response spectrum is a fundamental tool in the analysis and design of structures. A major portion of the chapter will be devoted to the presentation of earthquake response spectra and examples of their use. Specific topics include the relation s among various response spectra and between response and Fourier spectra, the role of damping, and the application of response spectra to single and multiple degree-of-freedom structures.

Another portion of the chapter will treat the use of spectral methods in earthquake resistant design, and primarily as an introduction to following more specialized chapters, some discussion of time history analysis and methods of analysis for special structures such as bridges, dams, pipelines, soil structures etc.

The chapter will close with the a list of general references.

Table of Contents

A. Single degree of freedom structures
B. Multi-degree of freedom structures, modal methods

6. Spectral methods of earthquake resistant design
   A. Design spectra
   B. Reduction for ductility
   C. Roles of analysis, building codes, standards and good practices

7. Time history analyses

8. Response of special structures and systems
   A. Dynamics of non-building structures: concrete and earth dams; bridges; storage tanks; power and communication systems, soil structures etc.
   B. Introduction to analysis of such structures and systems

9. References

** Manuscript submission date: August, 1998.

(7/97)

Chapter 58. Earthquake Resistant Design

Chris D. Poland, Degenkolb Engineers, San Francisco, CA, USA
and
Robert D. Hanson, University of Michigan, Mesa, AZ, USA

This chapter will provide a basic understanding of the earthquake resistant design process and its implementation through adequate construction quality control of materials and processes. The relationship between building code minimum lateral force requirements and procedures, and the response spectral methods described in Chapter 49 will be established. The importance of displacement control in the earthquake performance of the building will be used as an introduction to performance based design of new and seismic upgrading of existing buildings.

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** Manuscript submission date: August, 1999

(2/18/98)

Chapter 59. Finite Element Analysis in Earthquake Engineering

John F. Hall
California Institute of Technology, Pasadena, CA, USA

This chapter will cover applications of finite element analysis to buildings, bridges, protective systems, and dams. State-of-the-art analysis tools for these types of structures will be described, including nonlinear features, foundation interaction, dam-water interaction, etc. There will also be descriptions of typical types of earthquake behavior and damage mechanisms that the analysis tools try to predict.

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** Manuscript submission date: early summer 1999.

(8/12/97)

Chapter 60. Structural Monitoring, Isolation and Control

James L. Beck
California Institute of Technology, Pasadena, CA, USA

This chapter will provide an overview of technologies that enhance the safety of structures, such as buildings and bridges, which are subject to the threat of earthquakes. The emphasis will be on adding mechanical and electrical systems to a structure either to reduce the earthquake excitation, to passively or actively reduce its seismic response, or to continually monitor the integrity of the structure. These systems are potentially applicable during construction of new structures as well as for retrofitting existing structures.

The technologies which will be covered are: (a) seismic isolation - provision of a system to partially isolate the structure from strong ground motion using a flexible interface which is usually accompanied by added damping at the interface; (b) passive structural control - usually accomplished by adding damping devices based on either viscous fluid, viscoelastic material, hysteretic material or friction between two surfaces; (c) semi-active structural control - based on devices which provide low-power control of passive damping or resisting-force systems; (d) active structural control - based on mechanisms which actively provide controllable forces, usually by electrical or hydraulic actuation; and (e) structural health monitoring - uses (near) real-time monitoring of structural response to automatically detect if structural damage exists after an earthquake and, if so, to indicate its likely location and severity. Technologies (c), (d) and (e) are often grouped together under the umbrella of "smart structures" or "intelligent structures" because they involve sensing and computing hardware under the control of "decision-making" software.

The basic concept for each of these technologies will be described. Then the actual or potential benefits will be discussed along with the current challenges that must be met either to successfully develop and implement the technology or to enhance the effectiveness of existing systems. Examples of actual and potential installations of the systems will also be given.

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** Manuscript submission date: September, 1998.

(8/12/97)

Chapter 61. Liquefaction, Ground Failure and Inflicted Damage

T. Leslie Youd
Brigham Young University, Provo, UT, USA

This chapter will introduce liquefaction phenomena and consequent effects for the benefit of geologists, seismologists and other scientists interested in earthquake phenomena. Specialists in geotechnical engineering might find the chapter rather elementary. The chapter will concentrate on the review of the physical processes and mechanisms required to generate liquefaction along with types of ground deformations and ground failures induced by this phenomenon. Typical types of damage induced by liquefaction and ground failure will also be discussed. The discussion will be illustrated with pertinent case histories. Procedures for analyzing liquefaction, ground failure and consequent damage and for hazard mitigation will be noted and referenced, but space will not permit detailed discussion of these procedures.

Table of Contents

1. Introduction -- overview of liquefaction occurrences, damage, and socioeconomic impact.
2. Liquefaction mechanism and consequent ground deformation.
3. Types of ground failure, physical settings and consequent damage.
4. Analysis and mitigation of liquefaction hazard.
5. Concluding remarks

** Manuscript submission date: June, 1999.

(Note: Although much of the chapter will be written prior to this submission date, the submission will be held until near the deadline to allow incorporation of the latest developments in the field.)

(8/4/97)

Chapter 62. Lessons Learned from Past Earthquakes

Riley M. Chung, Toshio Iwasaki (?), and Li-Li Xie(?)

Earthquakes, when happened, can be devastating events that impact every aspect of mankind since civilization. Historical records showed repeatedly that even empires had been overtopped as a result of a destroying earthquake. Also through the civilization, the human race has been taking up the challenge by developing technologies to build an infrastructure that would resist the forces from earthquakes. Some worked, others failed. Even with the merging of new materials and new technologies, surprises would happen and have been happening in recent years. A case in point is the poor performance of steel frame buildings during the 1994 Northridge earthquake in California, United States and the 1995 Kobe earthquake in Japan. Where and when can the performance of various systems of our infrastructure be assessed? They are through the conduct of postearthquake investigations.

The aftermath from an earthquake striking an urban area provides a natural environment to evaluate how well our society's infrastructure can meet the challenge of natural forces from the earthquake. Infrastructure includes buildings and lifeline systems, where the latter refers to utilities and transportation systems. Utilities are the systems that provide electricity, gas and liquid fuels, water and sewer, and telecommunications, which are all vital to the welfare of our modern life. When assessing the performance of lifelines, the performance of the components in each system, as well as the performance of a system as a whole, should be examined. Likewise we should also examine the interdependent nature among the lifeline systems.

Lessons learned from postearthquake investigations can be most effective and most rewarding to determine what are working and what are not, as our knowledge and technologies were applied to build our modern society. Lessons learned from such investigations can also be most sobering in a way that often we have repeatedly been learning the same mistakes we had learned in the past. Lessons learned can also be disturbing since often the decision that led to the use or not-use of a particular technology was outside the realm of the limitation of technology. Instead, it can often be non-technical, such as economic constraint or politically oriented motive.

We move on with the successful tools and conduct R&D to replace the outdated and failed ones. We also improve the successful tools through the advancement of methodologies and new materials. Throughout the years, lessons learned from postearthquake investigations have become not only an integral part, but also the most critical avenue to advance our state of the art practices in addressing issues related to earthquake disaster mitigation.

This chapter provides an overview of the needs and objectives of postearthquake investigation. It presents the logistics prior to the investigation, what we are looking for when conducting it, and how the findings are filtered to R&D and their impacts on the modern design and construction practices. Lessons learned from earthquake events in the 20th century will be examined, especially those resulted from organized reconnaissance efforts, which in essence began since the 1964 Alaska earthquake. Particular attentions will be paid to more recent events. These would include the following earthquakes: 1972 Haichen, China; 1976 Tangshan, China, 1985 Chile, 1985 Mexico City, 1988 Armenian, 1988 Newcastle, Australia, 1989 Loma Prieta, 1990 Philippine, 1994 Northridge, and 1995 Kobe, Japan.

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** Manuscript submission date: February 1999

(3/16/98)

Chapter 63. Advances in Seismology with Impact on Earthquake Engineering

S. K. Singh, M. Ordaz, and J. F. Pacheco, Instituto de Geofisica, UNAM, Mexico

This chapter will emphasize those recent advances in seismology (including zero frequency seismology) which have direct impact on earthquake engineering. Topics would include source studies, seismicity and seismotectonics, geodynamics, propagation and attenuation of seismic waves, site effects, and estimation of ground motions during future earthquakes. It will include a list of outstanding problems.

Table of Contents

1. Introduction: Radical advances in seismic and geodetic instrumentation, communication technology, and computers have improved our knowledge of (a) seismic sources, (b) seismicity and seismotectonics, (c) geodynamics, (d) propagation and attenuation of seismic waves, (e) site effects, and (f) estimation of ground motion from future earthquake. Some of these improvements have direct impact on seismic hazard estimation.

2. Seismic source studies: Quasi realtime estimation of source parameters; detailed mapping of slip on the fault using local, regional and teleseismic seismograms, and geodetic measurements: paleoseismology; recurrence period and seismic gap hypothesis.

3. Seismicity and Seismotectonics: Better instrumentation and synthetic waveform modeling has permitted more reliable locations and focal mechanisms of small and moderate earthquakes, which, in turn, has improved our knowledge of the seismotectonics of many regions.

4. Geodynamics: Use of permanent and portable GPS receivers as well as traditional geodetic instruments promises to improve the current geodynamical models. It would provide more reliable relative plate motions and may help in deciding whether a fault zone is creeping or locked. Is a plate boundary segment, with no historical large/great earthquakes, a permanent seismic gap or it simply has a long recurrence period? Measurement of deformation may give us estimate of seismic hazard as a function of time.

5. Propagation and attenuation of seismic waves: A critical element in estimating ground motion at a site from an earthquake of given magnitude is the knowledge of propagation and attenuation of seismic waves. Wide spread use of better quality seismic instrumentation has given rise to more and higher quality data for theoretical modeling and for regression analysis.

6. Site effect: Recent earthquakes have shown that the site effects play a major role in causing damage during earthquakes. Examples are 1985 Michoacan Mexico earthquake, Armenian earthquake, Loma Prieta and Northridge earthquakes, and Kobe earthquake. Various techniques are being used: (a) spectral ratio technique, (b) fitting source model to the spectra, (c) coda waves, (d) microtremors, (e) spectral ratio of horizontal to vertical component of ground motion from earthquakes or microtremors.

7. Estimation of ground motion during future earthquakes: We need an adequate description of the earthquake source and a means to include the path (including the site) effect. The path effect can be included by using the attenuation relation derived from a regression analysis. Alternatively, theoretical or empirical Green's functions technique. Different approaches to describe the source, their advantages and disadvantages.

8. Some challenges: Hidden faults (Latur, Northridge, …), seismic potential of seismic gaps, truly "aseismic gap" or long recurrence period, M_{max} of region. Answer from seismology, GPS, and geology.

** Manuscript submission date: February, 1999.

(11/12/97)

Chapter 64. Earthquake Prediction

Hiroo Kanamori
California Institute of Technology, Pasadena, CA, USA

This chapter introduces the subject with some examples and definitions. Then a brief discussion will be made on the physical processes of earthquakes including short- and long-term crustal processes.

Several methods that have been used for short- and long-term predictions will be introduced with some caveats.

In addition to "short-term" prediction, some discussions will be made for intermediate- and long-term forecasts which will lead to long-term seismic hazard assessment.

Progress and difficulties in earthquake prediction and forecast will be summarized in an attempt to determine the future direction of earthquake research.

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** Manuscript submission date: April, 1999

(8/8/97)

Chapter 65. Seismic Hazards, Risk Assessment, and Building Code

Paul Somerville and Yoshi Moriwaki
Woodward-Clyde, Pasadena, CA, USA

Much of the groundwork for this chapter will be provided in the immediately preceding chapters 10 through 13, which address strong ground motion, the dynamics of building response, special analysis in earthquake engineering, and liquefaction, ground failure and inflicted damage.

This chapter will begin with a description of the nature of the information that is needed for performing a seismic hazard analysis, and the choices that must be made in developing the required information. It will describe the manner in which uncertainty in the input information is used to characterize the uncertainty in the estimated seismic hazard. Procedures that are currently used for quantifying seismic hazards using both scenario (deterministic) and probabilistic approaches will be described.

The chapter will then proceed to describe how this seismic hazard information is used in seismic risk assessment, through some form of relationship between the input ground motion level and its effects on structures such as buildings and earth embankments. Simple seismic risk assessments will be illustrated using examples that address seismically induced soil liquefaction and lateral displacement. The general methodology by which seismic hazard and seismic risk are addressed in earthquake engineering practice will be described. The manner in which earthquake engineering practice is codified in the seismic provisions of building codes, and the relationship of simple codified procedures to the underlying principles of earthquake engineering, will be described. The policy decisions concerning acceptable levels of risk that are implicitly or explicitly made in seismic risk assessments and in building codes will be described.

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** Manuscript submission date: June 31, 1999.

(Revised 11/12/97)

Chapter 66. Stress Triggers, Shadows, and Seismic Hazard

Ruth A. Harris
U. S. Geological Survey, Menlo Park, CA, USA

This chapter will provide an introduction to the numerous studies of earthquake interactions and summarize the body of work that has used simple static or dynamic Coulomb failure models to account for spatial and temporal earthquake patterns.

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** Manuscript submission date: February, 1999.

(3/26/98)

Chapter 67. Synthesis of Earthquake Science Information and Its Public Transfer

Keiiti Aki
Observatoire Volcanologique du Piton de la Fournaise, La Union, France

Earthquake science has made a quantum jump in the last three decades with the plate tectonic revolution, wide acceptance of fault model and advances in computer technology. As summarized in the present Handbook, it has matured with massive interactions between theory and observations, and successfully developed as a quantitative science. The increasing societal need for mitigating earthquake hazard is also an important factor for the development. In early days of earthquake science when it was at a rudimentary stage of development, individual scientists were asked by public to give advice on various issues. Because of the small number of scientists, any opinion tends to become personified; differences in opinion become polarized and sometimes lead to a personal tragedy. The present chapter describes an effective way of integrating earth science information regarding earthquakes in a region and transferring it to people living in the region. I shall use the case history of the Southern California Earthquake Center for illustration, because it has been widely recognized as a success from the points of both science and public.

I shall describe the events that led to the birth of the Center, and the concept of the master model of earthquakes in Southern California that helped to unite seismologists, geologists, geodesists, and geotechnical engineers through the critical period of two major earthquakes there, namely the Landers earthquake of 1992 and the Northridge earthquake of 1994. In fact, a first generation master model for earthquake source characterization in Southern California was born in the process of creating a public policy document in response to the public need for the probability of major earthquakes after the Landers earthquake. The Northridge earthquake emphasized the complexity of local site effects on strong ground motion, to which the Center responded quickly and effectively through cooperation of scientists of multiple disciplines and institutions. Excitement of doing creative science is as essential as effective public transfer of the product of science for a healthy development of a science. I shall describe how the concept of the master model served the dual purpose. Finally, the transportability of the concept to other regions of the earth will be discussed.

<u>Table of Contents</u>

** Manuscript submission date: April, 1998.

(11/24/97)

Chapter 68. The Sociological Dimensions of Earthquake Mitigation, Preparedness, Response and Recovery

Dennis S. Mileti, and Paul W. O'Brien
University of Colorado, Boulder, CO, USA

This chapter will provide a state-of-the-art summary of what is known regarding the societal dimensions of earthquake hazard mitigation, preparedness, response and recovery. The empirical scientific research record will be reviewed and synthesized for individuals and households, organizations, and communities. The chapter will provide explanations for how and why individuals and families, organizations, and communities do and do not mitigate, prepare, respond to, and recover from earthquakes.

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** Manuscript submission date: February, 1999

(12/3/97)

Chapter 69. Reducing Earthquake Hazards in Developing Countries*

*** This Chapter is being organized now. ***

Chapter 70. Earthquake Early Warning Systems

J. M. Espinosa Aranda
Centro de Instrumentacion y Registro Sismico, Mexico City, Mexico

Purpose of the chapter is to expose the Earthquake Early Warning Systems as a practical means for earthquake mitigation and rapid response.

Area of emphasis will be: benefits obtained by the use of the warning signal by people, emergency services and industry. Its low cost of implementation and operation. Social impact of EWS improving earthquake preparedness.

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** Manuscript submission date: June 1, 1999

(8/12//97)

Chapter 71. Statistical Principles for Seismologists

David Vere-Jones, Victoria University, Wellington, New Zealand
Yosihiko Ogata, Institute of Statistical Mathematics, Tokyo, Japan

The aim of this chapter is to give an overview of basic principles, mostly without proofs, with illustrations and tutorial examples drawn from seismology, and references for further reading and explanation.

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** Manuscript submission date: February, 1999.

(4/6/98)

Chapter 72. Relationships between Earthquake Magnitude Scales

T. Utsu, Tokyo, Japan

This Chapter will be an English translation of the main part of the paper with the same title published in the Bulletin of the Earthquake Research Institute, University of Tokyo, Vol. 57, p. 465-497, 1982 (in Japanese) with additional notes and revised figures.

This paper treats the relationships between various magnitude scales: Ms (surface-wave magnitude based on the original Gutenberg formula, taken from Gutenberg-Richter's and Abe's catalogs), M_S (ISC) and M_S (USGS) (surface-wave magnitudes using the IASPEI formula), m_B (body-wave magnitude using medium-to-long-period records, taken from Gutenberg-Richter's and Abe's catalogs), M_b (ISC) and m_b (USGS) (body-wave magnitudes using short-period records), M_L (magnitude for local earthquakes based on Richter's original definition), M_W (moment magnitude), M_{JMA} (magnitude assigned by JMA to earthquakes in Japan).

** Manuscript submission date: February, 1999

(4/17/98)

Chapter 73. Seismic Velocities and Densities of Rocks*

N. I. Christensin, University of Wisconsin, USA

***** Chapter outline not yet available *****

Chapter 74. Significant Earthquakes of the World

Compiled by
William H. K. Lee, U. S. Geological Survey, Menlo Park, CA, USA
and
Hiroo Kanamori, California Institute of Technology, Pasadena, CA. USA

This chapter will contain a chronological table of about 1,000 earthquakes that are of interest to scientists and engineers.

We will compile materials from available sources and will attempt to summarize the events as objectively as possible. Variations and uncertainties will be noted, and additional materials will be appended in the CD-ROM.

We will also compile a comprehensive review of about 60 notable earthquakes -- our selections are obviously subjective with emphasis on more recent earthquakes with abundant and/or unique data, and the availability of someone who is willing to do the review. Each reviewed earthquake will be written by an invited author; the full review will be placed on the CD-ROM with 1-paragraph summary to be placed on the printed volume. We are now in the process of selecting and inviting authors for these reviews. Authors agreed to write are indicated in [ ] after the earthquake. A "?" after the author indicates that the author has been invited, but has not yet agreed to contribute a review.

Table of Contents (tentative)

(21) Ningxia-Kansu, China, December 16, 1920
(22) Kanto, Japan, September 1, 1923
(23) Tango, Japan, March 7, 1927
(24) Sanriku, Japan, March 2, 1933
(25) Long Beach, California, March 11, 1933
(26) Hsinchin-Taichung, Taiwan, April 21, 1935
(27) Erzincan, Turkey, December 27, 1939
(28) Chillan, Chile, January 24, 1939
(29) El Centro, Imperial Valley, May 18, 1940
(30) Tonankai, Japan, December 7, 1944

(31) Nankaido, Japan, December 20, 1946
(32) Assam-Tibet, August 15, 1950
(33) Kern County, California, July 21, 1952
(34) Kamchatka, Russia, November 4, 1952
(35) Dixie Valley-Fairview Peak, Nevada, December 16, 1954
(36) Aleutian Is., March 9, 1957
(37) Gobi-Altai, Mongolia, December 4, 1957
(38) Chile, May 22, 1960
(39) Prince William Sound,Alaska, March 27, 1964
(40) Niigata, Japan, June 16, 1964

(41) Matsushiro, Japan, August 3, 1965
(42) Parkfield, California, June 27, 1966
(43) San Fernando, California, February 9, 1971
(44) Lima, Peru, October 3, 1974
(45) Haichen, China, February 4, 1975
(46) Guatemala, February 4, 1976
(47) Tangshan, China, July 27, 1976
(48) Caucete, Argentina, November 23, 1977 [J. S. Carmona?]
(49) Imperial Valley, California, October 15, 1979
(50) Michoacan, Mexico, September 19, 1985

(51) Whittier Narrows, California, , October 1, 1987
(52) Spitak, Armenia, December 7, 1988
(53) Loma Prieta, California, October 18, 1989 [T. Holzer].
(54) Landers, California, June 28, 1992
(55) Latur, India, September 29, 1993
(56) Northridge, California, January 17, 1994
(57) Sakhalin, Russia , 1995
(58) Kobe, Japan, January 17, 1995

4. Chronological Table of About 1,000 Significant Earthquakes

5. References

** Manuscript to be submitted: August, 1999.

(3/31/98)

Chapter 75. An Inventory of Data from Seismographic Networks of the World

John C. Lahr (Coordinator), U.S. Geological Survey, Denver, CO, USA
Randall A. White (Coordinator), U.S. Geological Survey, Menlo Park, CA, USA

This chapter is intended to document and archive basic seismic data in the form of earthquake catalogs from seismic networks all over the world. These will be included with the Handbook on one or more attached CD-ROMs. An untold amount of time, effort, and resources have been devoted to the operation of regional and global seismic networks and the generation of earthquake catalogs and station bulletins. Inclusion of these data in the Handbook will provide a means of guaranteeing that these data will be preserved and available for research and study far into the future. For more information on this chapter, please visit the Website at: http://lahr.org/iaspei

Specifically, this chapter will be a compilation of instrumental earthquake catalogs or "station bulletins" from around the world, and will consist of many sub-chapters. Seismologists will be asked to contribute instrumental earthquake catalogs or "station bulletins" from their networks that they believe to be reasonably complete within a specified time period. For publication consideration, the following materials must be submitted:

1. An abstract of about 1/2 page to be included in the printed volume of the Handbook.
2. A description of the seismic network, including station history, coordinates, and instrumentation.
3. A description of the data processing and limitations of the data, including velocity structure model(s), method(s) for computing hypocenter parameters, magnitude(s), etc.
4. An earthquake catalog in the form of computer readable ASCII file(s), with explanations of the format.
5. The phase data files used in deriving the earthquake catalog with an explanation of the format(s).
6. References.

In practice, we expect all the computer files listed above will be submitted via floppy disk(s), IOMEGA Zip disk(s), CD-ROM(s), or "ftp". Item (5) is optional if these data have already been archived in a public data bank or have been published on CD-ROM(s); in this case, a description of how to access them or a reference to a publication will be adequate.

All submitted materials will be reviewed by two reviewers. In order to maintain a high standard, only earthquake catalogs that pass the review will be accepted.

(6/15/98)

Chapter 76. An Inventory of Strong-Motion Data of the World

David J. Wald (Coordinator), U S. Geological Survey, Pasadena, CA, USA
J. Carl Stepp (Coordinator), Earthquake Hazards Solutions, Austin, TX, USA

This Chapter is intended to document and archive strong-motion data of the world, mostly for magnitude 6 or greater earthquakes. A Website is now being set up by the coordinators and details will be announced soon.

Chapter 77. Notable Seismological and Earthquake Engineering Institutions

To be compiled by the editors; We will request major institutions to contribute; 1 printed page for each institution; about 50 printed pages total; additional materials will be placed on the CD-ROM). The following list with proposed author in parenthesis is very tentative and the order is arbitrary. However, the published list will be alphabetical. We welcome suggestions and comments.

1. International Association of Seismology and Physics of the Earth's Interior (C. Friodevaux).
2. International Association of Earthquake Engineering (S. Cherry).
3. International Seismoloigcal Centre (R. Willemann).
4. International Institute of Seismology and Earthquake Engineering (H. Mizuno).
5. Seismological Society of Japan (M. Ishida).
6. Seismological Society of America (R. J. Archuleta).
7. Seismology Section of the American Geophysical Union (B. A. Romanowicz).
8. Earthquake Engineering Research Institute (J. Niggs).
9. IRIS (D. Simpson).
10. Southern California Earthquake Center (T. Henyay and D. D. Jackson).
11. Seismological Laboratory of California Institute of Technology (H. Kanamori).
12. Seismological Laboratory of University of California, Berkeley (B. A. Romanowicz).
13. Earthquake Hazards Program, U. S. Geological Survey (J. Filson).
14. Lamont-Doherty Earth Observatory (?).
15. Department of Terrestrial Magnetism, Carnegie Institution of Washington (?).
16. Earthquake Engineering Research Laborat*ry of Caltech (W. D. Iwan).
17. Mid-America Earthquake Center, U. of Illinois (D. P. Abrams).
18. Pacific Earthquake Engineering Research Center, UC Berkeley (J. P. Moehle).
19. Center for Advanced Technologies in Earthquake Loss Reduction, SUNY Buffalo (G. C. Lee).
20. Blume Earthquake Engineering Center of Stanford University (A. S. Kiremidjian).
21. Earthquake Research Institute of Tokyo University (Y. Fukao?).
22. National Research Institute for Earth Science and Disaster Prevention of Japan (M. Ishida).
23. Disaster Prevention Research Institute of Kyoto University (?).
24. State Seismological Bureau of China (?).
25. National Geophysical Research Institute of India (H. Gupta).
26. Institute of Physics of the Earth, Russia (?).
27. Institut de Physique du Globe de Paris (?).
28. Istituto Nazionale di Geofisica of Italy (E. Boschi).
29. Institute of Geological & Nuclear Sciences, New Zealand (G. McVerry).
30. Geophysical Laboratory, Aristotle University of Thessaloniki (B. C. Papazachos).
31. Institute of Earth Science, Academia Sinica, Taipei (Y. H. Yeh).

Chapter 78. Biography of Notable Seismologists and Earthquake Engineers

S. Miyamura, et al. *(Compilers)*

A biography of some notable scientists and engineers (who have contributed greatly to the study of earthquakes and their mitigation, directly or indirectly) will be compiled from existing obituaries and available sources. Selections will be limited to those who have deceased by 1997.

Each biography will include a description of the position(s), important contributions and major works. The full biography will be placed on the attached CD-ROM; only a brief summary (normally 1 paragraph) will be printed on paper. About 150 persons around the world will be selected. Tentative selection list is shown below, and we welcome suggestions and comments. Persons willing to write the biographies are indicated by names enclosed in [ ].

Table of Contents (tentative)

Freeman, John R. (1855-1932; USA)
Fuller, M. L. (USA) -- New Madrid earthquakes (1811-1812)

Galitzin, B. B. (1862-1916; Russia)
Geiger, L. (Germany)
Gerland, G. (1838-1919; Germany) -- organizer of Intnational. Association of Seismology
Gilbert, Grove Karl (1843-1918; USA)
Gu, Gong-Xu (China) -- for organizing the State Seismological Bureau of China
Gutenberg, Beno (Germany/USA)

Haskell, N. A. (USA)
Hattori, J. (Japan) -- first president of Seismological Society of Japan
Heck, N. H. (USA)
Hodgson, Ernest A. (Canada)
Hodgson, J. H. (Canada)
Honda, H. (Japan)

Imamura, Akitune (Japan)
Ishimoto, M. (Japan)

Jacobsen, Lydik S. (USA)
Janczewski, E. W. (Poland) – [Jerzy Kowalczuk]
Jeffreys, Harold (1891-1989; Great Britain)

Karnik, Vit (Czech)
Kawasumi, H. (Japan)
Kikuchi, Baron Dairoku (Japan) -- Earthquake Investigation Committee
Klotz, Otto (Canada)
Knott, C. G. (Great Britain)
Koto, Bunjiro (1856-1935; Japan)
Krishna, Jai (India)

Lawson, Andrew C. (USA)
Lee, S. P. (China) -- modern pioneer of seismology in China.
Lehmann, Inge (1888-1993; Denmark)
Louderback, G. D. (USA)
Love, A. E. H. (Great Britain)

Macelwan, James B. (USA)
Mallet, Robert (1810-1881, Ireland)
McAdie Alexander G. (USA)
Mckay, Alexander (1841-1917; New Zealand)
Mercalli, G. (Italy)
Michell, John (1704-1793; Great Britain)
Milne, John (1850-1913; Great Britain)
Mohorovicic, Andrija (1857-1936; Croatia)
Mueller, Stephan (Germany/Switzerland)
Murphy, L. M. (USA)

Naito, Tachu (Japan)
Nasu, N. (Japan)
Navier, Claude. (1785-1836; France)
Nersesov, Igor L. (Russia)
Neumann, Frank (USA)

Newmark, Nanthan M. (USA)
Nuttli, Otto W. (USA)

Oakeshott, G. B. (USA)
Oddone, E. (Italy)
Oldham, Richard Dixion (1858-1936; Great Britain)
Omori, Fusakichi (1868-1923; Japan)

Pachetnik (Russia).
Palazzo (Italy) -- first president of International Association of Seismology
Panetti, M. (Italy)
Pekeris, Chaim L. (Israel)
Perrey, Alexis (1807-1882; France)
Poisson, Simeon Denis (1781-1840; France)

Raitt, R. W. (USA)
Rayleigh, Lord (John William Strutt; 1842-1919; Great Britain)
Reid, Harry Fielding (USA)
Richter, Charles F. (1900-1985; USA)
Riznichenko, Iu. V. (Russia)
Rosenblueth, Emilio (Mexico)
Rossi, M. S. de (Italy)
Rothe, E. (France)
Rothe, Jean-Pierre (France)
Rudzki, M. P. (Poland) – [Slawomir Maj].

Sano, R. (Japan)
Savarensky, E. F. (Russia)
Schmidt, Johann F. J. (1825-1884; Germany)
Schuster, A. (Great Britain)
Seed, H. Bolton (USA)
Shebalin, N. V. (Russia)
Stokes, George Gabriel (1819-1903; Great Britain)
Stoneley, R (Great Britain)
Suess, Eduard (1831-1914; Austria) -- author of Das Antlitz der Erde (1903)
Suyehiro, Kyoji (Japan) -- author of "Engineering Seismology" (1932)

Terada, Torahiko (Japan)
Tocher, D. (USA)
Townley, S. D. (USA)
Tsuboi, C. (Japan)
Turner, H. W. (-1930; Great Britain)
Tuve, M. A. (USA)

Ulrich, F. P. (USA)

Von Kovesligethy, R. (Hungary) -- first secretary of International Association of Seismology
Von Rebeur-Paschwitz, E. (Germany)

Wadati, Kiyoo (Japan)
Wiechert, E. (Germany)
Willis, Bailey (USA)
Willmore, Patrick L. (Great Britain)
Wilson, James T. (USA)

Wilson, J. Tuzo (Canada)
Wood, H. O. (USA)

Zoeppritz, K. (Germany)

Chapter 79.1. Software for Earthquake and Engineering Seismology: A Survey

Mariano Garcia-Fernandez, Instituto de Ciencias de la Tierra, Barcelona, Spain
and
Walter W. Hays, U. S. Geological Survey, Reston, VA, USA

This Chapter will survey some useful and commonly available software for earthquake and engineering seismology, almost all for the IBM-compatible personal computers. It will include complete information on the IASPEI software: the Seismological Software Library (SSL) and the PC Shareware Library (PCSL).

The SSL is an attempt to provide useful seismological software for the IBM-compatible personal computers. It is different from most commercial software in that source codes written by the IASPEI authors are also published. At present 6 volumes have been published and additional volumes will be published in the future.

The PCSL main objective is to provide fast and wide distribution of geophysical software, complementing the existing SSL. Unlike SSL, programs in PCSL are not critically reviewed, but can be shared freely. The PCSL Second Edition includes 34 programs and it is published on CD-ROM. The programs will be soon also available on a ftp server. Information on other available non-commercial seismological software will be also included, plus selected comercial software commonly used in earthquake and engineering seismology.

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** Manuscript submission date: June 30, 1999

(8/11/97)

Chapter 79.2. SAC2000: Signal Processing and Analysis Tools for Seismologists and Engineers

Peter Goldstein, Doug Dodge, and Mike Firpo
Lawrence Livermore National Laboratory, Livermore, CA, USA

SAC2000 is the rebirth and evolution of Lawrence Livermore National Laboratory's (LLNL's) Seismic Analysis Code (SAC) developed during the 1980s for a variety of geophysical applications. SAC2000's strengths include its ability to process a diverse range of data types, its extensive, well-documented signal processing capabilities (both on-line and on the web at: http://www-ep.es.llnl.gov/tvp/sac.html), its macro language, and its ability to do both batch and interactive processing. Its extensive usage (> 300 institutions worldwide) has also made it much easier for researchers to develop collaborative research projects. SAC2000's extensive signal processing capabilities include: data inspection, signal correction, and quality control, unary and binary data operations, travel-time analysis, spectral analysis including high-resolution spectral estimation, spectrograms and binary sonograms, and array and three-component analysis.

Recent developments in SAC2000 include: enhanced compatibility with the CSS3.0 database schema, complete compatibility with the widely used SEED data format instrument responses, map making capabilities via an interface to GMT, a new three-component polarization and phase identification tool, an external interface that allows users to define their own commands, and an interface to MATLAB that allows the user to use MATLAB commands and scripts on SAC data from within SAC2000. We have also implemented a number of commands to enhance user efficiency and numerous improvements and enhancements to many individual SAC commands.

Current developments in SAC2000 are motivated by the need for easy and efficient access to and processing and interpretation of large amounts of data. We are also driven by the need to communicate results from SAC2000 to our database and other programs. Based on these needs, we have begun developing a new, internal data structure for SAC2000. This new structure will be completely compatible with the standard SAC format but will also allow us to access, modify, and output all the information in CSS3.0-based Oracle databases or CSS3.0 flat files. Given the variety of data types that are currently possible in SAC2000 and other programs, and the likelihood that additional data types or parameters will be needed in the future, we are designing SAC2000's new format to be easily extendable and anticipate incorporation of significant extensions to the CSS3.0 schema.

This research was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

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** Manuscript submission date: September 1998.

(8/11/97)

Chapter 79.3. The SEISAN Earthquake Analysis Software and the SEISNET Data Collection Software

Jens Havskov and L. Ottemoeller
University of Bergen, Bergen, Norway

A main goal of any processing system is to have a database where all data and results of analysis are stored and easily accessible for further work. The main advantage of SEISAN is that it unites standard programs with a simple data base so that all routine and most research task can be carried out in one processing system. In addition, processing can be done in the same way on different computer platforms and data can be moved from e.g. Sun to PC without any format conversions. The main emphasis of the SEISAN description is then to describe the capabilities of SEISAN and its integration with other formats and processing systems as given in the contents below.

A major task of any data center is to manually or automatically collect data from different types of seismic stations. SEISNET is an aromatic data collection and event detection software written in EXPECT and running on Sun. SEISNET can link Internet or modem connected stations to become a seismic network. SEISNET works with several different types of seismic stations of which the most important is the IRIS station. SEISNET is tightly integrated with SEISAN data base structure and processing.

Table of Contents

5. Introduction of SEISNET

    Basic philosophy of SEISNET
    SEISAN and SEISNET integration
    System requirements

6. How to Use SEISNET

    Setting up a network
    Setting trigger and processing parameters
    Example of a network of IRIS stations
    Instruction of how to adopt your own stations for SEISNET

** Manuscript submission date: August, 1998.

(Revised 2/28/98)

Chapter 79.4. ORFEUS Seismological Software Library (SSL)

Torild van Eck and Bernard Dost
ORFEUS, AE De Bilt, The Netherlands

This chapter contains an overview of seismological software and related software libraries available through the Internet. ORFEUS is a European non-profit organisation that aims at coordinating and promoting digital, broad-band seismology in the European-Mediterranean area. The Seismological Software Library (SSL) is one of the activities launched to achieve this goal.

The main purpose of ORFEUS SSL is to promote the availability of relevant seismological software. In practical terms this means that the ORFEUS staff with the help of working group members (1) maintains a library containing web- and ftp-links to relevant seismological software and related software libraries, and (2) stimulates discussions within Europe around the Fissures initiative of the IRIS Data Management System Standing Committee.

The ORFEUS SSL also includes a mirror of part of the seismological software cited in the library in order to promote availability. Further, a preliminary effort has been made to provide an overview of available conversion software.

The electronic SSL can be found on ORFEUS web pages:

http://orfeus.knmi.nl/working.groups/wg4/

Not only will you find a broad selection of practical seismological programs fairly general used within the scientific community, also large electronic libraries on mathematics, numerical problem solving, statistics, physics, etc can be found.

Purposely, we excluded, with a few exceptions, commercial software, as we believe they will reach their appropriate clients allready through their own marketing efforts. Obviously, such an effort is dynamical, as programs improve, change, are being replaced etc., while peoples addresses, web- and ftp-sites change. But most importantly, new languages like Java stimulate a different approach to software programming and applications. Therefore, we think an electronic SSL is best suited to serve the seismological community. Even better than dissemination through disks or CD-ROMs, as these do not offer the capability of keeping up-to-date.

A number of practical problems remain to be solved, such as protection of authorship and effective means to stimulate broader discussions around program bugs, improvement, etc. within the scientific community without twarting commercial interests.

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** Manuscript submission date: August 31, 1999

(11/25/97)

Chapter 79.5. USGS Moment Tensor Software and Catalog

Stuart A. Sipkin
U.S. Geological Survey, Denver, CO, USA

This chapter will contain descriptions of A) the method used to routinely compute the USGS moment tensor solutions, B) the data used, and C) the catalog coverage and format.

A) Briefly, the solutions are computed using an algorithm based on the theory of optimal filter design. In this algorithm the far-field Green's functions are the multichannel input, the observed seismograms are the desired output, and the moment-rate tensor is the convolution filter that is solved for. For a given focal depth the inversion is linear, and depth is determined by finding the focal depth for which the normalized mean-squared error is minimized. The moment tensor is decomposed into both its principal axes, including the associated eigenvalues, and a "best" double couple.

B) The solutions are computed using the P-wave group (including surface reflections) from broadband digital seismograph stations at teleseismic distances, ~30-95 degrees in epicentral distance. The instrument response is first removed, and the microseisms are filtered out with a low-pass filter with a corner period at 13 sec. For very large events the corner is moved out to longer periods.

C) The catalog begins in 1981, but several significant events in 1980 are also included. From 1981 through 1994 the lower magnitude threshold is approximately 5.7-5.8, with an average of approximately 125 events per year. Since 1995, mainly due to the rapid expansion of the global, digital seismograph networks, this threshold has been lowered to 5.5, with an average of approximately 250 events per year.

Rapidly determined moment tensor solutions are computed within hours of an event's occurrence. Final solutions are published in the Monthly Preliminary Determination of Epicenters (PDE), approximately four months after the end of a given month.

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** Manuscript submission date: August 31, 1999.

(11/12/97)

Chapter 79.6. The FDSN/IRIS Data Management System: Providing Easy Access to Terabytes of Information

Tim Ahern
IRIS DMC, Seattle, WA, USA

IRIS is funded by the National Science Foundation (NSF) to support the seismological infrastructure needed by the global seismological research community. Two programs of IRIS are responsible for generating data from the IRIS Global Seismic Network (GSN) and from the Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL). The IRIS Data Management System (DMS) is the third core program of IRIS and it is responsible for archiving, maintenance and distribution of the data generated by the GSN and PASSCAL programs and by other organizations that contribute data to the Data Management Center (DMC).

At the present time IRIS has nearly 6 terabytes of compressed seismic data. Roughly 3 terabytes are from the IRIS GSN, 1 terabyte from the IRIS PASSCAL program, 1 terabyte from vari_us arrays operated by IRIS, 0.6 terabytes from the Federation of Digital Seismographic Networks (FDSN) and the remainder from a variety of other data sources. One of the major accomplishments of IRIS and the FDSN has been to standardize the format of data from more than 50 different data sources and present data in a uniform manner to the seismological community. IRIS projects that it will be managing approximately 50 terabytes of data shortly after the beginning of the next century.

The DMC maintains all parametric information about the waveforms and seismic events in an Oracle DBMS that allows rapid determination of data characteristics. The waveforms data are stored in one of several mass storage systems at the DMC. A one terabyte RAID serves as a temporary buffer that holds data for several months before transfer to a large 50 terabyte mass storage system for final archiving and safekeeping. The DMC has developed a variety of data request tools that make it easy for users to request data from selected earthquakes or data from the archive in a simple manner.

In 1997 the DMC will service approximately 50,000 requests for seismic data containing about 18 million seismograms with a volume of about 0.8 terabytes. Perhaps the most striking statement concerning the DMC is that nearly as much data are shipped to users each year as the primary data generating components send to the DMC.

In the future, we anticipate that IRIS may become more actively involved in the development of a framework that can be used to develop the software systems that will be required to manage the increasing amounts of seismic data.

Table of Contents:

4. Statistical summary of the output of the IRIS DMC

5. Other Services
   Documentation
   Application Software

6. Future Developments and Activities
   Application Software
   Documentation
   New Methods of Delivering Data

7. Conclusions

** Manuscript submission date: August, 1998

(Revised 3/7/98)

Chapter 80. Resources for Earthquake and Engineering Seismology

This chapter will provide "pointers" for readers to look up information that is not covered by the Handbook. It may include:

80.1 Intenet Access (S. Malone)

80.2 Education and Outreach (J. Andrews)

80.3 Bibliographic Sources

Chapter 80.1. Seismology and the Internet

Steve Malone
University of Washington, Seattle, WA, USA

I propose to write a brief summary of the use being made of the Internet by earthquake seismologists for the acquisition and exchange of seismic data as well as the distribution and publication of both data and research results. This will start with the birth of the Internet in the 1970s where one of the first nodes on the original ARPA net was the machine "seismo" at the Center for Seismic Studies. It will include the Internet's early use for exchanging programs and small data sets on an ad hoc basis via FTP and progress to its use by the end of the century for almost all aspects of digital communications. The printed text will include brief summaries of the Internet's uses in seismology at the end of the century with the following headings. The expanded CD-ROM section will give the details with both printed and URL references to a fairly comprehensive list of examples.

Table of Contents

1. Data Acquisition: Examples of seismographs which are directly connected to the Internet, intermittently connected through PPP dial-up, and those which are indirectly connected through data concentrators or centers for real-time data acquisition.

2. Data Exchange: Examples of data center to data center and data center to researcher both in near real-time and in batch mode.

3. Data distribution: Examples of ways that final users receive data from data centers, intermediate processing facilities, and data set concentrators. This includes traditional weak-motion seismology as well as strong-motion engineering data sets.

4. Information distribution: Examples of ways that intermediate and final users can rapidly receive the results of routine analysis and research. This includes not only other seismologists and earth scientists but also educators, emergency managers, the press and the general public.

5. Publication: How has the Internet changed the way publication of data and research results are handled.

** Manuscript submission date: August, 1999.

(4/29/98

Chapter 80.2. Inquiry-based Education Programs and Research-based Technology Development and Transfer

Jill Andrews
University of Southern California, Los Angeles, CA, USA

The chapter will describe an issues-based approach to building an education and outreach program, and will provide details of projects and products that illustrate the most successful "tools" for educating and motivating the ever-growing and vulnerable urban populations in seismically active regions.

The chapter will begin with a series of common concerns among educators, researchers and professionals who wish to improve their earth science-related education and outreach efforts: What can we do to facilitate the use of existing and developing knowledge bases? How do we encourage better communication among researchers, educators, students, practicing and consulting professionals, and public officials? What tools can be used to raise the level of awareness and encourage loss reduction activities among all stakeholders in at-risk communities? How do we forge alliances and partnerships with others to encourage an integrated approach to our education and outreach efforts? What are we missing in our collective quest to encourage application of new knowledge?

The chapter will use a narrative format to address these issues, and will emphasize six general principles on which we at the Southern California Earthquake Center base our successful education and outreach programs. Although numerous methods, models, and strategies exist, the challenges we continue to face are to apply these six principles in selecting the right kinds of projects and activities, target the appropriate audiences, and present them at the right places and at the right times.

The chapter will lead the reader through a short tutorial that covers the six principles with examples to illustrate each:

1. Internal Investigation: conducting an inventory of internal source strengths and capabilities in the context of user needs as a first step toward education and application.

2. Identification of "user" groups appropriate to earthquake-related education, information, knowledge and technology; reaching consensus on vision, goals, objectives and products to simplify and facilitate the process.

3. Initiation of a mutually-influencing network that involves representatives from identified end user groups, such as those responsible for risk reduction in the built environment, land use, disaster preparedness and response, and education systems.

4. Interaction with the network as an integral part of the education and outreach program: inviting user participation within a research-oriented environment.

5. Implementation of a work plan that incorporates application of research results and encourages continuous, open communication among researchers, educators and users.

6. Iteration of the process to refine products, strengthen linkages, and expand opportunities, leading to joint ownership, consensus and implementation of mutually-identified priorities.

The chapter will describe sample programs, sponsored by SCEC and others, that are designed to fulfill the SCEC Education and Outreach mission: to promote earthquake loss reduction and to actively engage the public at large in activities that focus on earthquake-related education, research-based technology development and transfer, and systemic reform. It will cover the importance of alignment to State and National Science Education Standards and to the National Mitigation Strategy; how to encourage public participation in and understanding of earthquake science; how to promote enhancement of K-12 programs; how to develop and distribute educational products that highlight earthquake research; and how to emphasize career development of earth science students in high school and college. We will suggest ways to organize and develop for application the growing knowledge bases of academic scientists, engineers, and social scientists, with a view to reducing earthquake-related risks. We will suggest activities designed to encourage societally-based systemic reform (e.g., better building practices, code upgrades, introduction of legislative initiatives) through interactive workshops, symposia, and continuing education programs that target two audiences: the community of scientists and technical professionals working in related fields, and the general public.

Finally, the chapter will encourage readers interested in successful education and outreach programs to create multi-dimensional enterprises that provide useful products while engaging all sectors of the community at large. The summary section of the chapter will touch on the importance of education and outreach program directors acting as effective brokers of information between the academic community and practitioners, between earth scientists and engineers, between technical professionals and public officials, and between scientists and educators. The summary will address the usefulness of interactive workshops, monthly or quarterly publications, Internet connectivity and creation and maintenance of educational web sites, development of web-based education modules, partnerships in industry and education, and database development and management.

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(4/25/98)

Chapter 81. Miscellaneous Data of Seismological Interests*

*** This Chapter is being organized now. ***

Chapter 82. Technical Glossary of Earthquake and Engineering Seismology

In this chapter, we will attempt to compile a technical glossary of terms used in earthquake and engineering seismology. Most of the source materials will be contributed by the authors of this Handbook.

To get started, we have compiled glossary terms from the following publications for Handbook authors to consider in their chapters:

(1) {a&r80}: Aki and Richards, "Quantitative Seismology", 1980.
(2) {bol93}: Bolt, "Earthquakes", 1993.
(3) {cam87}: Campbell, "Engineering Seismology", 1987.
(4) {jea87}: Jeanloz, "Earth's Mantle", 1987.
(5) {kov95}: Kovach, "Earth's Fury", 1995.
(6) {l&S81}: Lee and Stewart, "Microearthquake Networks", 1981.
(7) {lee87}: Lee, "Observational Seismology", 1987.
(8) {rik87}: Rikitake, "Earthquake Prediction", 1987.
(9) {ste82}: Steinbrugge, "Earthquakes, Volcanoes, and Tsunamis", 1982.
(10) {ysa97}: Yeats, Sieh and Allen, "The Geology of Earthquakes", 1997.

Kanamori's comments dated 8/12/97 are noted as {kan97}.
Lee's comments dated 8/13/97 are noted as {lee97}.

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acceleration	{kov95}
accelerometer	{bol93}
accelerogram	{lee97}
accelerograph	{lee97}
acceptable risk	{ysa97}
ACH method	{lee97}
acoustic emission	{lee97}
active fault	{bol93}, {kov95}, {rik87}, {ysa97}
active tectonics	{ysa97}
aftershock	{lee87}, {ste82}, {ysa97}, {bol93}, {kov95}
air waves	{a&r80}
AIC (Akaike's information criterion)	{lee97}
Airy phase	{a&r80}
aliasing	{lee97}
ambient vibration	{lee97}
amplitude	{ysa97}
amplitude (of ground motion)	{ste82}
amplitude (wave)	{bol93}, {kov95}
anisotropy	{lee97}
anomaly	{lee97}
arrival	{lee97}
ART (Algebraic reconstruction technique)	{lee97}
aseismic creep	{kov95}
aseismic front	{ysa97}
aseismic region	{bol93}, {ste82}

aseismic slip	{kan97}
asperity (fault)	{bol93}, {ysa97}
asthenosphere	{bol93}, {jea87}, {kov95}, {ysa97}
attenuation	{bol93}, {ste82}, {ysa97}
auxiliary fault-plane	{bol93}
auxiliary plane	{kan97}
azimuth	{lee97}
b value	{ysa97}
back-arc basin	{ysa97}
back-projection method	{lee97}
Backus-Gilbert inversion	{lee97}
barrier (fault)	{bol93}
base shear coefficient (equivalent lateral force)	{kov95}
bearing wall (of a building)	{ste82}
Benioff zone	{bol93}, {kov95}
Benioff-Wadati zone	{kan97}
blind fault	{ysa97}
blind thrust	{ysa97}, {bol93}
body wave	{bol93}, {ysa97}, {a&r80}, {lee87}
body-wave magnitude	{bol93}
bracing	{kov95}
brick-joisted (building)	{ste82}
brittle-ductile transition	{ysa97}
brittle-plastic transition	{lee97}
building code	{lee97}
broad-band seismometer	{lee97}
Brune model	{lee97}
bulk modulus	{bol93}
buoyancy	{kan97}
Burger's vector	{lee97}
Byerlee's law	{lee97}
caldera	{ste82}, {ysa97}
capable fault	{bol93}, {ysa97}
centroid moment tensor (CMT)	{lee97}
characteristic earthquake	{bol93}, {ysa97}
coda	{bol93}, {ysa97}
coda magnitude	{l&s81}
coda waves	{lee87}, {a&r80}
coefficient of internal friction	{ysa97}
coefficient of friction	{kan97}
cohesion	{ysa97}
comb fracture	{ysa97}
concrete -- poured-in-place, precast, prestressed	{ste82}
converted waves	{a&r80}
core (earth's)	{lee87}, {kov95}, {bol93}, {ysa97}
core-mantle boundary	{lee97}
coseismic	{ysa97}
Coulomb fracture criterion	{ysa97}
covariance	{lee97}
covariance matrix	{lee97}
Crary waves	{a&r80}
craton	{ysa97}

creep (along a fault) {ysa97}, {ste82}, {bol93}
crust (earth's) {lee87}, {bol93}, {kov95}, {ysa97}

D" Layer {jea87}
damping {bol93}, {ste82}, {ysa97}
decollement {ysa97}
deep-focus earthquakes {kov95}
delay {lee97}
density {bol93}, {ysa97}
depth phases (pP, pS, sP, sS) {a&r80}
design earthquake {ysa97}
design ground motion {cam87}
detachment fault {lee97}
deterministic hazard assessment {ysa97}
differential settlement {ste82}
diffracted P {a&r80}
diffraction {lee97}
digital filter {lee97}
digital signal processing (DSP) {lee97}
digitization {lee97}
dike {ysa97}
dilatancy {rik87}
dilatancy (of rocks) {bol93}
dip {bol93}, {ysa97}
dip-slip fault {bol93}, {ysa97}
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Chapter 83.1. Fault and Earthquake Imagery on Land

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As the title implies, this sub-chapter will present imagery of faults, fault zones, and earthquake-related damage. The intended product will be a CD composed of high-resolution digital imagery, wherever possible made from original slides or negatives. Emphasis will be placed on content, resolution, and a comprehensive coverage of faults and earthquake effects. A broad range of fault types and expressions of faults will be presented. Also, a range of geographic coverage is planned, with images from all over the Earth (but limited to on-land features). Fault imagery will include photographs from on the ground, oblique aerial photos, vertical aerial photos, and satellite imagery. With regards to more remote imagery, this sub-chapter will avoid “derivative” and “non-picture” imagery, such as satellite interferometry, X-ray imagery, etc. and rather will be restricted to imagery palatable to the mind’s eye and readily recognizable as faults and fault features. Further, the sub-chapter will avoid overlap with the planned CD of images from Schwartz, Pantosti, and Okamura, which will show paleoseismic evidence of faulting. Images of earthquake effects will come from all over the world, and will include effects from modern and historic earthquakes.

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Chapter 84. A User Guide To the IASPEI Centennial CD-ROM

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This chapter is a user guide to the attached IASPEI Centennial CD-ROMs. The CD-ROM is an economical way to distribute large amount of information. It will be prepared with the latest available technology, and will be readable by any computer equipped with a standard CD-ROM reader.

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